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B[illegible]osystem-A[illegible]sphere Study (BOREAS)

[illegible]ll and Karl Huemmrich, Editors

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[illegible]AS TF-10 NSA-Fen Tower Flux
[illegible] Data

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Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Karl Huemmrich, Editors

Volume 207

BOREAS TF-10 NSA-Fen Tower Flux and Meteorological Data

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National Aeronautics and
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BOREAS TF-10 NSA-Fen Tower Flux and Meteorological Data

J. Harry McCaughey, Dennis Jelinski

Summary

The BOREAS TF-10 team collected tower flux and meteorological data at two sites, a fen and a young jack pine forest, near Thompson, Manitoba, Canada, as part of BOREAS. A preliminary data set was assembled in August 1993 while field testing the instrument packages, and at both sites data were collected from 15-Aug to 31-Aug. The main experimental period was in 1994, when continuous data were collected from 08-Apr to 23-Sep at the fen site. A very limited experiment was run in the spring/summer of 1995, when the fen site tower was operated from 08-Apr to 14-Jun in support of a hydrology experiment in an adjoining feeder basin. Upon examination of the 1994 data set, it became clear that the behavior of the heat, water, and carbon dioxide fluxes throughout the whole growing season was an important scientific question, and that the 1994 data record was not sufficiently long to capture the character of the seasonal behavior of the fluxes. Thus, the fen site was operated in 1996 in order to collect data from spring melt to autumn freeze-up. Data were collected from 29-Apr to 05-Nov at the fen site. All variables are presented as 30-minute averages. The data are stored in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TF-10 NSA-Fen Tower Flux and Meteorological Data

1.2 Data Set Introduction

The meteorological data collected from the fen and Young Jack Pine (YJP) towers represent, in some sense, polar opposites of the range of surface climate conditions expected in the boreal forest. The fen is normally characterized by abundant water close to, or located at, the surface, whereas the

YJP site can be one of the driest surfaces in the boreal forest. Jack pine generally inhabit well-drained, sandy soils where, in the absence of regular precipitation, a significant water deficit can develop. The data presented here bear out the contrast in the surface climate conditions experienced by the two sites. For example, in the driest periods in the summer of 1994 it was common to measure mid-afternoon Bowen ratios in the range of 10 to 15, leading to the characterization of the site as a "Green Desert"; at the same time, the typical Bowen ratio at the fen seldom exceeded 1.0, and was usually closer to 0.8.

The YJP site can be fairly described as a fast response surface in that there were major and rapid changes in flux behavior, especially in evaporation, as the site was wetted or when it dried down. No such behavior could be ascribed to the fen because of the steadier supply of surface water.

A broad array of supporting data was also collected to describe the surface's state and to provide the information, in association with the flux data, to build Soil-Vegetation-Atmosphere-Transfer (SVAT) models. At the fen, our ancillary data collection focused upon the spatial pattern of vegetation present on the fen. These ancillary data are available upon request from the Principal Investigator (PI) for the fen site, Dr. D. Jelinski.

1.3 Objective/Purpose

This project is concerned with the spatial heterogeneity of surface energy fluxes in the northern boreal forest. The study was designed to compare surface radiation, energy, water, CO_2 fluxes, and their biophysical controls at both wetland and upland forest sites within the northern boreal forest. Specific objectives of the study were as follows:

- To quantify the differences between surface-atmosphere interactions between the sites.
- To compare hydrological estimates of basin evaporation to modeled water loss values (computed from knowledge of the vegetational composition of homogeneous landscape units and their ecotones, and the functional response of these units to climatic forcing.
- To provide continuous tower fluxes of water, sensible heat, CO_2 in support of the development of SVAT models at the stand and regional scales.

Data for this study were collected on two sites in the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) at Thompson, Manitoba: a young jack pine forest (YJP), and a fen wetland.

1.4 Summary of Parameters

The following variables were measured at the fen: net radiation, incoming and reflected solar radiation, incoming and outgoing longwave radiation, incoming and reflected photosynthetic photon flux density (PPFD), wind speed, wind direction, wet- and dry-bulb temperature, soil temperature, soil heat flux, sensible heat flux, latent heat flux, CO_2 flux, rainfall, and water level.

1.5 Discussion

The primary objective of this project was to develop a full suite of radiation, energy, and CO_2 flux measurements for the two flux tower sites. At both towers, identical instrumentation was used for data collection. The measurement systems used can be briefly summarized as follows:

- Radiation balance fluxes, including PPFD, were monitored using standard instrumentation mounted near the top of the flux towers.
- Soil heat flux (G) was measured using soil heat flux plates combined with calorimetric calculations of heat storage (see Sections 4.1 and 9.1).
- Convective fluxes of latent (LE) and sensible (H) heat were measured directly via the eddy covariance technique.
- Net CO_2 flux (Fe_{CO2}) was measured using an eddy covariance system; this system consisted of a single-axis sonic anemometer and a fast-response infrared CO_2 gas analyzer. The air intake was located at the same level as the sonic anemometer, and air was drawn down to the gas analyzer at the base of the tower. Lag times between the gas analyzer signal and the sonic anemometer signal were included in the online processing of the flux; offline processing included heat flux density corrections (Webb et al., 1980) and CO_2 storage in the air layer between the intake and the surface.

Flux data were supported with accompanying meteorological measurements. At each site, profiles of wind speed, temperature, and humidity were measured in the lower boundary layer. In addition, soil and biomass temperatures, wind direction, and rainfall were monitored.

Tower data at both sites were collected from 15-Aug to 31-Aug-1993. In 1994, the YJP tower was operational almost continuously from 23-May to 30-Sep, and the fen tower was operational from 08-Apr to 23-Sep. Before 01-Jun, only convective energy fluxes and the supporting profile data were measured at the fen to support an associated hydrological study of snowmelt in an adjoining basin during the Focused Field Campaign (FFC) from 12-Apr to 02-May. CO_2 flux data came online at the fen by 01-Jun-1994. In 1995, only the fen was operational to support the continuation of the hydrological experiment; data were collected from the tower from 15-Apr to 10-Jun. In 1996, the measurement period at the YJP extended from 08-May to 07-Nov at the fen, data were collected from 29-Apr to 05-Nov.

1.6 Related Data Sets
BOREAS AFM-07 SRC Surface Meteorological Data
BOREAS HYD-01 Volumetric Soil Moisture Data
BOREAS TGB-01/TGB-03 NEE Data over the NSA Fen
BOREAS TF-11 SSA-Fen Tower Flux and Meteorological Data
BOREAS TF-10 NSA-YJP Tower Flux, Meteorological, and Porometry Data

2. Investigator(s)

2.1 Investigator(s) Name and Title
Dr. J. Harry McCaughey
(Principal Investigator at NSA-YJP)
Department of Geography
Queen's University

Dr. Dennis E. Jelinski
(Principal Investigator at NSA-Fen)
Department of Geography
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Two PIs were associated with the Tower Flux (TF)-10 group: Harry McCaughey and Dennis Jelinski. Harry McCaughey oversaw the tower fluxes at both the NSA-YJP and the NSA-Fen sites. Dennis Jelinski was responsible for the vegetation work at the NSA-Fen site. Peter Lafleur shared responsibility for measurements at both sites. David Fitzjarrald (Principal Investigator for the TF-08 group) kindly loaned the TF-10 team a sonic anemometer and associated equipment that were used at the NSA-Fen site in 1996. The TF-10 team is grateful for Dr. Fitzjarrald's contribution, his help with field deployment of the equipment, and his advice at all stages of the work. As well, the TF-10 team acknowledges the help and advice of Kathy Moore and R.K. Sakai, members of the TF-08 team.

In addition, a large group of very competent graduate students, field assistants, and technicians contributed to the overall success of the work. Special mention goes to David Joiner and Paul Bartlett (Queen's University). David developed and built the CO_2 measurement system. Paul started work as a technician in the group and later stayed at Queen's University as a doctoral student. He made many contributions, but special mention must go to his work on assembling and organizing the deployment of equipment in 1993 and to his porometry work at the YJP site in 1994 and 1996. Andrew Costello (Queen's University), helped in the field setup in 1993 and did most of the initial stand measurements on the YJP canopy. He was assisted by Blair Mantha from Trent. Bob Metcalfe, Queen's and Trent, worked on an associated hydrology project focused upon the feeder basin north of the fen. He was supervised jointly by Jim Buttle, Trent University, and Harry McCaughey. Mike Skarupa and Greg Bryant, Trent, assisted in the data collection efforts at both sites. Kristan Boudreau was an outstanding field assistant and she performed excellent work in 1994 in all facets of the experiments at both sites.

Bruce Robertson and Derek Mueller were able field assistants in 1996.

Finally, a special thanks to Laura Liblik, who did the majority of the work associated with the preparation of the data before its submission to the BOREAS Information System (BORIS). Her attention to detail, her writing, and her editorial skills are much appreciated.

2.2 Title of Investigation

Surface Energy and Water Balances of Forest and Wetland Subsystems in the Boreal Forest - Surface Atmosphere Links and Ecological Controls

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3. Theory of Measurements

Many of the individual measurements made during the study involved routinely collected data obtained with a single instrument (e.g., incoming solar radiation and temperature measurement with thermocouples). Such measurements represent standard data collection techniques, and specific, detailed elaboration is not provided in this report. However, there is discussion of some limited aspects of these routine measurements where such detail is required for a complete understanding. Readers are referred to the manufacturers' specifications for details on the theory of measurement and operation of individual instruments.

The following section describes only the measurement method used for the fluxes.

Sensible (H) and latent (LE) heat fluxes, and the net flux of CO_2 (Fe_{CO2}) (net ecosystem exchange, NEE) were found using the eddy covariance technique (Campbell and Unsworth, 1979; Tanner et al., 1993). Fluxes are computed as the time-averaged product of the fluctuations of vertical wind velocity (w') and fluctuations of the appropriate scalar (the covariance). For example, fluctuations of temperatures (T') for H, water vapor density (q') for LE, and CO_2 concentration (C') for Fe_{CO2}, give:

$$LE = L <w'q'> \qquad (3.1)$$

$$H = rho\ Cp <w'T' \qquad (3.2)$$

$$Fe_{CO2} = rho(c) <w'C' \qquad (3.3)$$

where L is the latent heat of vaporization of water (J/kg), rho is the density of air (kg/m^3), Cp is the specific heat of air at constant pressure (J/kg/°C), rho(c) is the density of CO_2 (kg/m^3), and the < > symbol represents a time averaged product or covariance.

In practical terms, the eddy covariance technique is very sensitive to site conditions and instrument response. For one-dimensional measurements the site is assumed to be perfectly flat. This eliminates net positive or negative horizontal advection. Ideally, the response time of the instrument should be fast enough to monitor the complete spectrum of frequencies occurring in the turbulent flow. However, the total response is determined by the response time of the individual sensor, the instrument size and orientation, and the capacity to monitor the signal. Where two sensors are required, one to monitor w' and the other to monitor the appropriate scalar variable (T', q', or C'), then separation of the instruments in horizontal space introduces a possible error of mismatched frequencies sensed by the two systems. It is desirable to have the instruments as close together as possible; however, this can result in distortion of the wind field of one instrument by the presence of the other. A compromise is needed to overcome these two opposing problems, and sensors are typically placed 0.30 m to 0.40 m apart. Given the current status of data logging capacity, eddy covariance instruments are usually sampled at a rate of 10 Hz or greater.

4. Equipment

4.1 Sensor/Instrument Description

Micrometeorological Instruments

Meteorological and flux data at both sites were collected with similar instrumentation. Instruments were mounted on towers as described in Section 4.1.2. A listing of instrumentation follows.

- Net radiation was measured with a net pyrradiometer (model CN-1 Middleton, Carter-Scott Design, Victoria, Australia) aspirated with dry nitrogen gas.
- Incoming and outgoing solar radiation was measured with pyranometers (model 8-48, Eppley Laboratories Inc., Newport, RI, USA).

- Outgoing longwave radiation was measured with a pyrgeometer (model PIR, Eppley Laboratories Inc., Newport, RI, USA).
- Incoming and outgoing PPFD were measured with quantum sensors (model LI-Q190SA, LI-COR, Inc., Lincoln, NE, USA).
- Absolute wet- and dry-bulb temperatures were measured with psychrometers constructed from PVC tubing covered with reflective tape. Ventilation was supplied by a 12-volt DC fan that gave an air flow between 4-6 m/s across the sensor. The sensors were single-junction 24 a.w.g. copper-constantan thermocouples sealed with epoxy in stainless steel tubing (250 mm in length, 3.5 mm in diameter). The wet-bulbs were covered with cotton wicking to a length of 150 mm.
- Wind speeds were measured with 3-cup anemometers (model 12102, R.M. Young Co., Traverse City, MI, USA). The anemometers contained a DC generator that produced an analog signal proportional to wind speed.
- Wind direction was measured with a vane (model 12302, R.M. Young Co., Traverse City, MI, USA) containing a potentiometer that designated direction as proportional to the voltage output.
- Rainfall was measured with tipping bucket gauges (model TE252M, Campbell Scientific, Inc., Logan, UT, USA).
- Soil temperatures were measured with single-junction copper-constantan thermocouples (24 a.w.g.) fixed into a 3.18-cm-diameter wooden dowel inserted into the soil. Two soil temperature rods were installed at each site in order to sample soil temperatures below different cover types.

  At the fen, one soil temperature rod was installed in a moss hummock where the zero level (effectively the surface of the moss) was, on average, 25-30 cm above the water table. The second rod was placed in an adjacent hollow, where zero was effectively at the mean water table level. In each location, temperatures were measured at depths of 1, 5, 10, 25, 50, 75, 100, 150, and 200 cm during both 1993 and 1994.
- Soil heat flux was measured at each site with two soil heat flux plates (model HFT-3, Radiation Energy Balance Systems, Inc. (REBS), Seattle, WA, USA). Values from these instruments, combined with the soil temperature profiles, were used to calculate soil heat flux at each site as follows.

  At the fen, measurements were taken at a depth of 2 cm below the moss surface at a hummock and at a depth of 7.5 cm below the surface water in a hollow, which corresponded to a depth of 17 cm below the moss surface of the hummock. Heat flux plates, traditionally used to measure the soil heat flux, are known to perform poorly in organic (peat) soils. This may occur because the thermal conductivity of the plate is usually much greater than that of organic material and/or because it is difficult to get good thermal contact between the plate and the surrounding soil. For these reasons, it is recommended that heat flux plate readings be adjusted with a correction factor determined from calorimetric calculations of total heat storage (Halliwell and Rouse, 1987). According to this technique, heat storage in distinct soil layers is calculated from soil heat capacity and measured temperatures. Heat storage in each layer is accumulated, and conduction beneath the lowest layer is added to compute total heat storage. This value is then divided by the heat flux value measured from the plate to give a correction factor. The calculations are usually done over periods of several days, and the correction factor is applied to the half-hourly heat flux plate measurements (see Section 9.1). We divided that it was necessary to use a correction factor only for the 1994 data set. In 1996, the values of soil heat flux measured by the plates in the hummock and hollow were reasonable, and applying a correction similar to that used in 1994 would have produced values of flux that were unreasonably high. It was concluded that the thermal contact between the plates was better in 1996 than in 1994. However, it must be acknowledged that the measurement of heat storage in a fen remains a scientific concern.
- Data Logging: All tower variables (except eddy covariance) were recorded on data loggers (model CR7X, Campbell Scientific, Inc., Logan, UT, USA). The eddy covariance signals were recorded on data loggers (model 21X, Campbell Scientific, Inc., Logan, UT, USA).

- CO_2 concentration and flux densities were measured with a system designed at Queen's University by D. Joiner. It consisted of a single-axis sonic anemometer (mentioned above) and a fast response infrared gas analyzer (IRGA) (model LI-6252, LI-COR, Inc., Lincoln, NE, USA).

  Air is drawn by an AC pump from the intake of a tube (1/4" i.d. Bev-a-line IV) situated on the sonic anemometer arm to the IRGA at the base of the tower. The flow is split before reaching the IRGA, and the line to the IRGA passes through a fine particle filter. Air from the IRGA passes a pressure transducer (model PX142, Omega Engineering, Stamford, CT, USA) and a mass flow sensor (model 5860E, Brooks Instruments Division, Hatfield, PA, USA).

  Cross-correlation analysis was used to determine the travel time of the air from the tube inlet to the gas analyzer. The CO_2 flux density was then determined with the eddy covariance technique by finding the covariance of the 10-Hz direct output from the gas analyzer with time-lagged vertical wind velocity measured with a one-dimensional sonic anemometer (model CA-27, Campbell Scientific, Inc., Logan, UT, USA).

  The direct output from the IRGA was calibrated once a day using calibration gases flowing through the gas analyzer at the same pressure as that of the air down the tower. These field calibrations, linear over the range of ambient CO_2 concentrations and unchanging with temperature, were constantly corrected for pressure changes recorded with the gauge pressure transducer.

  Data processing and storage were done on data loggers (model 21X, Campbell Scientific, Inc., Logan, UT, USA), using the covariance at 10-Hz data and a 15-minute averaging subinterval. The CO_2 flux data were corrected for fluctuations of temperature and water vapor density during postseasonal analysis (Webb et al., 1980).

  Absolute concentrations of CO_2 were calculated using the factory calibration equation supplied with the LI-6252 and were corrected for air pressure fluctuations. Station values for air pressure (obtained from the Thompson airport) were entered daily as a constant into the data loggers. Daily field calibration of the IRGA showed that the absolute concentration may exhibit a drift of up to 3 ppmv over a 24-hour period.

  Final CO_2 flux density values combine the contributions from both the eddy flux and the changes in CO_2 storage for the volume of air beneath the eddy covariance instruments.

Biophysical Instruments

Water level in the fen was monitored continuously at the tower with an electronic water level recorder, which consisted of a weighted float connected to a potentiometer. The continuous output of the potentiometer is proportional to the relative water level in the fen. Water level is reported as a relative height in mm from an arbitrary datum. The datum zero represented the water level on the first day/hour of measurements: day of year (DOY) 230 at 1800 Universal Time Code (UTC) in 1993, DOY 127 at 1030 UTC in 1994, and DOY 140 at 2300 UTC in 1995.)

4.1.1 Collection Environment

The instruments were operated mainly under summer conditions with maximum temperatures around 35 °C. Data were collected over the growing season of 1994, the spring of 1995, and the spring through fall/winter of 1996. In the spring and fall/winter seasons, more extreme low temperatures were experienced. During these periods, the environment was more severe, and freezing temperatures were common; the lowest temperatures experienced were around -30 °C.

4.1.2 Source/Platform

The towers erected at the YJP and fen sites were 12-meter-tall triangular communications type, guyed on three sides, and anchored into the mineral soil. At the fen, the mineral soil was approximately 6 m below the mean surface. A floating boardwalk was constructed from the shore to the tower, and a 2.44-m by 2.44-m platform was built at the base of the tower.

At both sites, all sensors were mounted on the towers with fixed aluminum (3.18 cm diameter) extension arms, with the exception of the eddy covariance equipment, which was mounted on a swivel system, allowing for orientation of the instruments into the wind. Sensor height above the surface, distance from the tower, and orientation (degrees from magnetic north) are given in Table 1.

Table 1. Sensor heights on the flux tower at the fen in 1993, 1994, 1995, and 1996. The orientation of the arm holding the sensor is given in degrees measured from magnetic north, and the distance (m) from the tower is given. The symbol n/a, indicating "not applicable," means that no measurements were taken. The orientation of the arm holding the sonic anemometer and the krypton hygrometer was variable on a swivel mount that could be set anywhere from 150° from magnetic north through 360° to 55° from magnetic north.

Variable [Sensor]	Height(m)				Distance (m)	Orientation (degrees)
	1993	1994	1995	1996		
Incoming Solar Radiation [pyranometer]	10.47	10.47	10.47	10.47	1.5	135
Outgoing Solar Radiation [pyranometer]	10.23	10.23	10.23	10.23	1.5	135
Outgoing Longwave Radiation [pyranometer]	10.33	10.33	10.33	10.33	1.5	265
Net Radiation [net pyrradiometer]	10.45	10.45	10.45	10.45	2.3	155
Incoming PPFD [quantum sensor]	10.49	10.49	10.49	10.49	1.5	145
Outgoing PPFD [quantum sensor]	10.31	10.31	10.31	10.31	1.5	145
Wet- and Dry-bulb Temperatures [thermocouples]						
Level 1	2.57	2.50	2.50	2.50	0.6	295
Level 2	3.59	3.25	3.25	n/a	0.6	295
Level 3	4.65	4.00	4.00	n/a	0.6	295
Level 4	5.75	5.00	5.00	n/a	0.6	295
Level 5	6.55	6.00	6.00	6.00	0.6	295
Level 6	7.65	7.50	7.50	n/a	0.6	295
Wind Direction [vane]	7.65	6.00	6.00	6.00	1.4	24
Wind Speed [cup anemometer]						
Level 1	3.59	2.50	2.50	2.50	1.4	24
Level 2	4.65	3.25	3.25	n/a	1.4	24
Level 3	5.75	4.00	4.00	4.00	1.4	24
Level 4	6.55	5.00	5.00	n/a	1.4	24
Level 5	7.65	6.00	6.00	6.00	1.4	24
Vertical Wind Speed [sonic anemometer]	6.00	4.50	4.50	4.50	1.0	150-360-55
Vapor Density [krypton hygrometer]	6.00	4.50	4.50	4.50	1.0	150-360-55
Relative Humidity [T/RH sensor]	n/a	n/a	n/a	4.00	0.2	25

4.1.3 Source/Platform Mission Objectives

The primary objective of the towers was to support the needed instrumentation.

4.1.4 Key Variables

The key meteorological variables are incoming and reflected solar radiation, PPFD, outgoing terrestrial radiation, net radiation, wet- and dry-bulb temperatures, wind speed, wind direction, latent and sensible heat fluxes, net CO_2 flux, soil temperature, biomass temperature, rainfall, and water level.

4.1.5 Principles of Operation

Sonic Anemometer

The sonic anemometer system (model CA27, Campbell Scientific, Inc., Logan, UT, USA) obtains the velocity fluctuations of vertical wind speed from the measured Doppler shift induced by the wind velocity on an ultrasonic frequency pulse broadcast across a 10-cm path. The effect of temperature on sound velocity is eliminated by determining the Doppler frequency from the difference between forward and reverse path observations. Electronic processing of the signals from the ultrasonic transducers produces a real-time analog output voltage in the range ±4.0 V DC.

Air temperature fluctuations for the Campbell Scientific eddy covariance system are measured with a fine-wire thermocouple mounted about 4 cm from the anemometer sound path. The thermocouple output is amplified to a ±4.0 V DC signal. The thermocouple temperature is referenced to the instrument case, which is thermally lagged and responds slowly to temperature changes.

Absorption Hygrometer

The absorption hygrometer (model KH20, Campbell Scientific, Inc., Logan, UT, USA) measures the ultraviolet light transmission across a nominal 1-cm path in a water vapor absorption band corresponding to a krypton emission line (Campbell and Tanner, 1985). Instrument response is at least sufficient to resolve fluctuations of 80 Hz. The instrument output is a voltage in the range 0 to 4 V DC. The signal strength may be subject to gradual diminution as a result of scale accumulation on the optical surfaces.

Longwave Radiation Measurement

The sensing surface of a pyrgeometer (model PIR, Eppley Laboratories, Inc., Newport, RI, USA) consists of a differential thermopile that measures net longwave radiation fluxes between itself and the sky or ground (depending on orientation). The dome of the pyrgeometer is composed of silicon with a vacuum-deposited interference filter on its inner surface. The composite dome transmission shows an abrupt transition between approximately 3 and 4 micrometers from complete opaqueness to maximum transparency.

The outgoing longwave radiation from the instrument is calculated using the temperature of its blackbody cavity and the Stefan-Boltzmann equation. This flux is added to the thermopile signal to get the total incoming flux. The temperature of the blackbody radiator can be measured using a thermistor.

The thermopile output signal is measured as a single-ended voltage in the Campbell Scientific CR7X data logger. The case thermistor is not polarized and is connected between an analog input channel and ground. A 1000-ohm resistor is connected between the analog input channel and a switched analog output channel (725 card). The thermistor is excited with 1350 mV across the 1000-ohm resistor, and the thermistor (pyrgeometer) temperature is calculated as a function of the thermistor voltage (a function of its resistance). This method corresponds to the protocol for using the Eppley pyrgeometer proposed by the National Atmospheric Radiation Center (NARC). This method does not use the pyrgeometer's battery-powered temperature compensation circuit, and no battery should be installed when using the pyrgeometer in this manner.

4.1.6 Sensor/Instrument Measurement Geometry

See Table 1 in Section 4.1.2.

4.1.7 Manufacturer of Sensor/Instrument

Mass flow sensor and control unit for eddy covariance system:
Brooks Instruments Division
Emmerson Electric Co.
407 W Vine St.
Hatfield, PA 19440
USA
(215) 362-3500

Sonic anemometer; krypton hygrometer; fine-wire thermocouple; CR7X and 21X data loggers; rain gauge (fen):
Campbell Scientific, Inc.
P.O. Box 551
Logan, UT, 84321
USA
(519) 354-7356

Sonic anemometer:
Applied Technologies, Inc.
Boulder, CO
USA

Pyranometer; pyrgeometer:
Eppley Laboratories, Inc.
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USA
(402) 467-3576

Net pyrradiometer:
Carter-Scott Design
22 Ailsa Street
Box Hill
Victoria, 3128
AUSTRALIA
+61-3-9899-4277

Pressure transducer; thermocouple wire:
Omega Engineering
One Omega Drive
P.O. Box 4047
Stamford, CT 06907
USA
(203) 359-1660

Soil heat flux plate:
Radiation Energy Balance Systems Inc. (REBS)
P.O. Box 15512
Seattle, WA 98115-0512
USA
(206) 624-7221

Cup anemometer; wind vane:
R.M. Young Co.
2801 Aero Park Drive
Traverse City, MI 49648
USA
(616) 946-3980

All other instruments were produced in the climate laboratories at either Queen's University or Trent University.

4.2 Calibration

Pyranometers, pyrgeometers, and net pyrradiometers used at both sites were calibrated at NARC, Atmospheric Environment Service (AES), Downsview, Ontario.

In addition, following the intersite calibration on net pyrradiometers performed in the field in 1994 with the roving REBS 6-net pyrradiometer (Hodges and Smith, 1997; Smith et al., 1997), a corrected set of net radiation data was calculated for the 1994, 1995, and 1996 experimental periods for both the fen and the YJP. The corrected net radiation data will potentially facilitate the intercomparison of flux behavior between the tower flux sites.

CO_2 concentrations for high- and low-span calibration gases were determined at the Carbon Cycle Research Section, AES, Downsview, Ontario, Canada.

Factory calibrations were used for several instruments, and the recalibration details for individual sensors are given below.

- Quantum sensors and porometer (LI-COR, Inc., Lincoln, NE, USA)
- Cup anemometers and wind vane (R.M. Young Co., Traverse City, MI, USA)

Following the 1993 field experiment, each individual calibration for the group of cup anemometers was checked using the wind tunnel at Trent University, and no changes were needed to the original factory calibrations. Because the potentiometer on the two wind vanes was set in the field each time the instruments were deployed, both can be considered to have had regular field calibration checks.

- Soil heat flux plates (REAS, Seattle, WA, USA)

The factory calibrations were accepted for all four transducers, two at each site.

- Rain gauges (Campbell Scientific, Inc., Logan, UT, USA, and Weathermeasure Corporation, Sacramento, CA, USA)

Routine calibration checks were done on all rain gauges by pouring a known amount of water into the gauge and noting the response. In all cases, the gauges were within the manufacturer's specification.

- Sonic anemometers and krypton hygrometers (Campbell Scientific, Inc., Logan, UT, USA)

The hygrometers at both the fen and the YJP sites were recalibrated in March 1994 following the 1993 experiment and before redeployment for the 1994 experiment. Minor changes resulted, but they were not large enough to require correction to the 1993 data.

Thermocouples

- For all thermocouples, the appropriate calibration equation available in the data loggers (Campbell Scientific, Inc., Logan, UT, USA) was used.

4.2.1 Specifications

Whenever a new calibration was determined for an instrument, the new calibration was applied from the time of the recalibration. There was no attempt to blend the calibrations before and after the recalibration. Any step-up or step-down in the data values as a result of recalibration was accepted. For all instruments, the calibration changes were minor, and there were no instances where a blending of the calibrations was necessary.

4.2.1.1 Tolerance

The precision of the measured meteorological variables and the corresponding transducers are summarized below.

Variable	Transducer	Precision
solar radiation	Eppley pyranometer	1 W/m^2
longwave radiation	Eppley pyrgeometer	1 W/m^2
net radiation	Middleton net pyrradiometer	1 W/m^2
PPFD	LI-COR quantum sensor	1 $\mu mol/m^2/s$
carbon dioxide concentration	LI-COR IRGA	1 ppmv
soil heat flux	REBS heat flux plate	1 W/m^2
air, soil, and biomass temperature	Copper/constantan thermocouple	0.1 °C
horizontal wind speed	R.M. Young cup anemometer	0.1 m/s
wind direction	R.M. Young wind vane	1°
relative humidity	R.M. Young T/RH sensor	1%
vertical wind speed	Campbell Scientific sonic anemometer	0.1 m/s
rainfall	Campbell Scientific tipping bucket	0.1 mm
rainfall	Weathermeasure tipping bucket	0.254 mm

4.2.2 Frequency of Calibration

All radiometers used in the study were on a regular, 2-year calibration cycle. This calibration frequency was increased during BOREAS, and each radiometer was calibrated before each major field experiment. Full calibrations were done in April 1994, October 1994, and March 1996.

One sonic anemometer (model CA27, Campbell Scientific, Inc., Logan, UT, USA) was recalibrated by the manufacturer in May 1995 following water damage to the instrument in September 1994 at the fen.

The krypton hygrometers from the YJP and fen were calibrated in 1993 before deployment in the field and were recalibrated in March 1994.

Calibrations were determined on all CO_2 reference gas tanks prior to both major field seasons in March 1994 and March 1996.

Routine calibration checks were made on the rain gauges, following the protocol suggested by the manufacturers, prior to their deployment in all field experiments. No calibration change was necessary to either gauge.

4.2.3 Other Calibration Information

A summary follows of the instruments used at each site along with their calibration histories.

Solar Radiation was measured using Eppley pyranometers. The instruments, identified by serial number, used at both sites for each experiment are given in Table 2.

Table 2. Eppley pyranometers used at the fen in all experimental years. Each pyranometer is identified by its serial number.

Table 2. Eppley pyranometers used at the Fen

Variable	Year			
	1993	**1994**	**1995**	**1996**
Kd	15889	13762	13762	13762
Ku	14713	13855	13855	13855

The calibration histories of the pyranometers are shown in Table 3. All calibrations remained stable through the BOREAS field periods, and the largest change in any calibration was -0.57%.

Table 3. Calibration history of the Eppley pyranometers used in all experimental years. The change in calibration is given as a percentage from the previous value. The units of calibration are microvolts/(Wm^2).

Table 3. Calibration history of the Eppley pyranometers

Serial number	Year	Calibration	%change in calibration
13762	1992	12.21	-1.12
	1994	12.14	-0.57
	1996	12.20	0.49
13855	1992	10.92	-0.55
	1994	10.89	-0.27
	1996	10.92	0.28
14713	1992	11.17	-0.62
	1994	11.14	-0.27
	1996	11.14	0.00
15889	1992	11.09	-1.10
	1994	11.05	-0.36
	1996	11.06	0.09

Longwave radiation was measured using Eppley pyrgeometers.

Eppley pyrgeometer (serial number 29583F3) was used at the fen from 1993 to 1996. The calibration history of the instrument is given in Table 4. The first calibration of instrument 29583F3 in 1994 proved to be wrong because of a malfunctioning reference temperature bath at NARC. This was corrected by a recalibration of the instrument the same year, and all of the data were corrected in postprocessing.

Table 4. Calibration history of the Eppley pyrgeometers used in all experimental years. The change in calibration is given as a percentage from the previous value. The units of calibration are microvolts/W/m^2.

Table 4. Calibration history of the Eppley pyrgeometers

Serial number	Year	Calibration	%change in calibration
29583F3	1993	3.97	-
	1994	3.62	-8.82 (calibration is suspect)
	1994	3.83	-3.53 (recalibration for 1994)
	1996	3.83	0.00

Net radiation was measured using Middleton net pyrradiometers. The instruments used are listed in Table 5.

Table 5. Middleton net pyrradiometers used in the field experiments. Each instrument is identified by serial number.

Table 5. Middleton net pyrradiometers

Serial number	Site
1330	Fen in 1993, and from DOY 97-145 in 1996
1333	Fen in 1994, and 1995, and from DOY 146 in 1996

The calibration histories of the net pyrradiometers are given in Table 6. For all net pyrradiometers, the calibration values are given separately for shortwave (SW), longwave (LW), and combined the arithmetic average of SW and LW. The combined value was used for all times of the day, including the nighttime, when only longwave radiation is present. All instruments had two calibrations in 1994. The first calibration proved to be wrong because of a malfunctioning reference temperature bath at NARC. This was corrected by a recalibration of the instrument the same year, and all of the data were corrected in postprocessing. With the exception of the aberrant first calibration in 1994, all instruments remained stable for the duration of the experiments; changes were normally less than 1% and the largest was less than 4%.

Table 6. Calibration history of the Middleton net pyrradiometers used in all experimental years. The change in calibration is given as a percentage from the previous value. The units of calibration are microvolts/W/m^2. Separate calibrations are given for shortwave (SW), longwave (LW), and combined the arithmetic average of the SW and LW values. The calibration constant (cal. constant) is the ratio of the SW to LW calibration.

Table 6. Calibration history of the Middleton net pyrradiometers

Serial number	Year	SW	% change SW	LW	% change LW	combined	% change combined	cal. constant
1330	1992	37.52	-0.87	35.18	-3.98	36.35	-2.42	1.07
	1994	38.16	1.17	32.40	-7.90	35.28	-2.94	1.18
	1994	37.55	0.08	34.82	-1.02	36.19	-0.44	1.08
	1996	35.54	-5.35	34.13	-1.98	34.84	-3.73	1.04
1333	1992	37.74	-2.15	34.90	-6.46	36.32	-4.27	1.08
	1994	38.41	1.78	32.85	-5.87	35.63	-1.90	1.17
	1994	38.17	1.14	34.62	-0.80	36.39	0.22	1.10
	1996	38.12	-0.13	35.17	1.59	36.64	0.69	1.08

PPFD was measured using LI-COR quantum sensors. Table 7 shows the instruments used at each site in each experimental year, and Table 8 gives the calibration constants.

Table 7. Quantum sensors used at the experimental sites and the variables measured: PPFDd is incoming PPFD, and PPFDu is reflected PPFD. Instruments are identified by serial number.

Table 7. Quantum sensors used

Serial number	Site	Variable
Q17605	Fen 1993 to 1996	PPFDd
Q16754	Fen 1993 to 1996	PPFDu

Table 8. Calibration constants in units of µmole/s/m^2/mv for the quantum sensors used in the experiments. The instruments are identified by serial number.

Table 8. Calibration constants

Serial	Calibration
Q17605	293.25
Q16754	355.87

CO_2 concentration and CO_2 flux density were measured using an IRGA (model LI-6252, LI-COR, Inc., Lincoln, NE, USA) and a sonic anemometer (model CA27, Campbell Scientific, Inc., Logan, UT, USA). Table 9 lists the IRGAs and the sonic anemometers used at both sites. Sonic 1353 was damaged by water seeping into the lower arm at the conclusion of the 1994 experiment. This instrument was repaired and recalibrated before being deployed again in 1996.

Table 9. The sonic anemometers and IRGAs used at the fen. The instruments are identified by serial number. No CO_2 flux was measured at the fen in 1995; the sonic anemometer measured the convective fluxes only.

Table 9. The sonic anemometers and IRGAs

	Serial number	Site
Sonic anemometer	1201	Fen in 1995, YJP in 1993, 1994, and 1996
	1353	Fen in 1993, 1994, and 1996
IRGA	IRG2-208	Fen in 1993, 1994, and 1996

Soil heat flux was measured using REBS soil heat flux plates. The calibrations of the plates and the sites where they were deployed are given in Table 10.

Table 10. Calibrations for the soil heat flux plates, in units of $W/m^2/mV$, and the sites where they were deployed. Individual plates are identified by serial number.

Table 10. Calibrations for the soil heat flux plates

Serial number	Calibration	Site
933060	40.0	Fen in 1993, 1994, 1995, and 1996
933061	38.7	Fen in 1993, 1994, 1995, and 1996

Horizontal wind speed was measured using 3-cup anemometers (model 12102, R.M. Young Co., Traverse City, MI, USA). These instruments have calibrations in units of mv at 1800 rpm, and this is combined with a second general calibration equation to convert rpm to m/s. The calibrations of the anemometers are given in Table 11.

Table 11. Calibration of the 3-cup anemometers used at each site for horizontal wind speed measurement at the levels identified; e.g., U1 is the anemometer at level 1. The units of the calibration are mv at 1800 rpm.

Table 11. Calibration of the 3-cup anemometers

Site: Fen				
	Year			
Level	**1993**	**1994**	**1995**	**1996**
U1	2400	2400	2400	-
U2	2397	2397	2397	2397
U3	2396	2396	2401	2395
U4	2401	2401	2401	-
U5	2399	2399	2399	2401

Relative humidity was measured using a combination temperature/relative humidity probe (model 41372VC, R.M. Young Co., Traverse City, MI, USA) at each site in 1996 (Table 12). The temperature is measured with an RTD sensor, and the relative humidity is measured with a capacitance element. This probe was ventilated naturally and shielded by a 12-level plate shield. Each probe has the same calibration and specifications (Table 13).

Table 12. Temperature/relative humidity sensors used at the sites in 1996.

Table 12. Temperature/relative humidity sensors used at the sites in 1996.

Model	Serial number	Site
41372VC	1762	Fen

Table 13. Calibration and specifications for the temperature/relative humidity sensor (model 41372VC, R.M. Young Co., Traverse City, MI, USA).

Relative humidity:	operating temperature: -10 °C to 60 °C
	measuring range: 0 to 100%
	accuracy at 20 °C: 2% from 0-90% RH
	3% from 90-100% RH
	stability: better than ± 2% RH for 2 years
	response time: 15 sec
	sensor element: Vaisala intercap
	output signal: 0-1 volt DC
Temperature:	calibrated measuring range: -50 °C to 50 °C
	accuracy at 20 °C: ± 0.3 °C
	output signal: 0-1 volt DC

Rainfall was measured using tipping bucket rain gauges at both sites in all years at the fen. The gauge (model TE525, Texas Instruments, supplied by Campbell Scientific, Inc., Logan, UT, USA) was at a height of 1 meter above the surface, and 1 tip of the gauge represented 1 mm of rain.

Atmospheric pressure was measured at each site in 1996 using a Vaisala pressure transmitter (model PTB 101B, Vaisala, Oy, Finland, and supplied by Campbell Scientific, Inc., Logan, UT, USA). Each instrument had been calibrated against a working standard in February 1996. The instrument at the fen was S/N R0940004.

5. Data Acquisition Methods

The outputs from all instruments producing voltages were recorded on data loggers. Data from the loggers' memories were downloaded at regular intervals to either cassette tape or electronic storage module, and all data were transferred in the field to microcomputers and backed up on either floppy diskette or 1-GB Jaz drives (Iomega Corporation, Fenton, MO, USA).

Specific details for each major system are given below.

- Tower data (except eddy covariance) -- All signals were recorded on data loggers (model CR7X, Campbell Scientific, Inc., Logan, UT, USA) at a scan rate of once per 10 seconds. Output was processed every 3, 15, and 30 minutes depending on the variable. Only 30-minute data are reported in the BORIS data base.

- Eddy covariance -- All signals were recorded on data loggers (model 21X, Campbell Scientific, Inc., Logan, UT, USA) at a scan rate of once per 0.1 seconds. Intermediate processing was done every 15 minutes, and output data were processed every 30 minutes.

6. Observations

6.1 Data Notes

See Section 6.2.

6.2 Field Notes

SPECIAL NOTES: 1993

All data were averaged over thirty minutes, starting on the hour and half-hour, and ending thirty minutes later. Sampling was continuous and each day's data is from 0600 UTC to 0600 UTC the next day.

- LONGWAVE_IN_1033CM was calculated as a residual.
- Small nighttime values for SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, PPFD_IN_1049CM, and PPFD_OUT_1031CM were set to zero to account for very slight zero depressions and elevations in the radiometers.
- HEAT_STORAGE_TOTAL is the sum of HEAT_STORAGE_LATENT_AIR, HEAT_STORAGE_SENSIBLE_AIR, and SOIL_HEAT_FLUX_HOLLOW_10CM.

Data Period: August 15/93 (DOY 227)

- Data collection began on DOY 228 at 0000.
- All wet bulb temperatures are flagged DOY 227-228(2015).

Data Period: August 16 - August 29/93 (DOY 228-241)

- WET_BULB_TEMP_465CM is flagged DOY 228(2030)-229(730), and 229(1830-2130).

SPECIAL NOTES: 1994

All data were averaged over thirty minutes, starting on the hour and half-hour, and ending thirty minutes later. For example, data tagged at 0630, were collected between 0600 and 0630. Sampling was continuous and each day's data is from 0600 UTC to 0600 UTC the next day.

- LONGWAVE_IN_1033CM was calculated as a residual.
- SOIL_HEAT_FLUX_FEN was calculated by multiplying SOIL_HEAT_FLUX_HOLLOW_10CM by a correction factor of 3.04 for DOY 132 through DOY 262 (see documentation for details).
- R_NET_1035CM_CORRECTED was calculated using day and night time equations developed by Hodges and Smith (1997) (see documentation for details).
- Small nighttime values for SOLAR_RAD_IN_1023, SOLAR_RAD_OUT_1045CM, PPFD_IN_1049CM, and PPFD_OUT_1031CM were set to zero to account for very slight zero depressions and elevations in the radiometers.
- HEAT_STORAGE_TOTAL is the sum of HEAT_STORAGE_LATENT_AIR, HEAT_STORAGE_SENSIBLE_AIR, and SOIL_HEAT_FLUX_FEN.

Data Period: April 8 - April 11/94 (DOY 098-101)

- PPFD_OUT_1031CM sensor installed on DOY 105 at 0030.
- SOIL_HEAT_FLUX_HOLLOW_10CM sensor installed on DOY 122 at 1900.
- WATER_LEVEL_DEPTH sensor installed on DOY 127 at 630.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM installed on DOY 101 at 630.
- SPECIFIC_HUMIDITY_450CM sensor installed on DOY 107 at 1700.

- CO2_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM sensors installed on DOY 151 at 1800.
- SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_TEMP_HUMMOCK_1CM, SOIL_TEMP_HUMMOCK_5CM, SOIL_TEMP_HUMMOCK_10CM, SOIL_TEMP_HUMMOCK_25CM, SOIL_TEMP_HUMMOCK_50CM, SOIL TEMP_HUMMOCK_75CM, SOIL_TEMP_HUMMOCK_100CM, SOIL_TEMP_HUMMOCK_150CM, SOIL_TEMP_HUMMOCK_200CM, SOIL_TEMP_HOLLOW_1CM, SOIL_TEMP_HOLLOW_5CM, SOIL_TEMP_HOLLOW_10CM, SOIL_TEMP_HOLLOW_25CM, SOIL_TEMP_HOLLOW_50CM, SOIL_TEMP_HOLLOW_75CM, SOIL_TEMP_HOLLOW_100CM, SOIL_TEMP_HOLLOW_150CM, SOIL_TEMP_HOLLOW_200CM, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM,WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM, WET_BULB_TEMP_750CM, VAPOUR_PRESSURE_250CM, VAPOUR_PRESSURE_325CM, VAPOUR_PRESSURE_400CM, VAPOUR_PRESSURE_500CM, VAPOUR_PRESSURE_600CM, VAPOUR_PRESSURE_750CM, RAINFALL_100CM and WATER_LEVEL_DEPTH values are missing on DOY 098 from 630-1700 and 1830 (start of field season) and on DOY 100 from 1700-1730 due to programming.
- SOIL_HEAT_FLUX_HOLLOW, all wet bulb temperatures, and all vapor pressures are missing DOY 98-131.
- WIND_SPEED_250CM is not available until DOY 98 at 1900 due to programming.
- WIND_SPEED_325CM is not available until DOY 103 at 0000.
- WIND_SPEED_400CM is not available until DOY 103 at 0030.
- WIND_SPEED_500CM is not available until DOY 103 at 1930.
- WIND_SPEED_600CM is not available until DOY 105 at 1530.
- WIND_DIR_600CM and WIND_DIR_STDEV_600CM are not available until DOY 104 at 220.
- SOIL_HEAT_FLUX_FEN, SOIL_HEAT_FLUX_HOLLOW_10CM, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOYs 098 through 101.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are frozen on DOYs 099 through 101.

Data Period: April 12 - April 25/94 (DOY 102-115)

- PPFD_OUT_1031CM sensor installed on DOY 105 at 0030.
- SOIL_HEAT_FLUX_HOLLOW_10CM sensor installed on DOY 122 at 1900.
- WATER_LEVEL_DEPTH sensor installed on DOY 127 at 630.
- SPECIFIC_HUMIDITY_450CM sensor installed on DOY 107 at 1700.
- CO2_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM sensors installed on DOY 151 at 1800.
- SPECIFIC_HUMIDITY_450CM values missing on DOYs 107 through 115.
- LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM values are missing on DOY 107 from 1600-600 and on DOY 108 from 630-600 due to weather.

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM values are missing on DOYs 110 from 2230-600, on DOY 111 from 630-1430, on DOY 112 from 1930-2030 and 2230-600, on DOY 113 from 630-600, on DOY 114 from 630-1600 and from 2100-600 and on DOY 115 from 630-1530 and 1730-600 due to weather.
- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOYs 104, 105, 110, 111 and 114.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are frozen on DOYs 102 through 115.
- WIND_SPEED_325CM is not available until DOY 103 at 0000.
- WIND_SPEED_400CM is not available until DOY 103 at 0030.
- WIND_SPEED_500CM is not available until DOY 103 at 1930.
- WIND_SPEED_600CM is not available until DOY 105 at 1530.
- WIND_DIR_600CM and WIND_DIR_STDEV_600CM are not available until DOY 104 at 220.

Data Period: April 25 - May 9/94 (DOY 116-129)

- DOY127(1800) RAINFALL_100CM and WATER_LEVEL_DEPTH are interpolated.
- SOIL_HEAT_FLUX_HOLLOW_10CM sensor installed on DOY 122 at 1900.
- WATER_LEVEL_DEPTH sensor installed on DOY 127 at 630.
- CO2_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM sensors installed on DOY 151 at 1800.
- SPECIFIC_HUMIDITY_450CM values are missing on DOY 116 through 129.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM values are missing on DOYs 116 from 630-1600 and from 2230-600, on DOY 117 from 630-1600, on DOY 119 from 2300-600, on DOY 120 from 630-1430, on DOY 121 from 2000-600, on DOY 122 from 630-2030 and from 2200-600, on DOY 123 from 630-600, on DOY 124 from 630-1530, on DOY 126 from 1600-600, on DOY 127 from 1830-600, on DOY 128 from 630-600 and on DOY 129 from 630-1500 due to weather.
- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOYs 117 and 118.
- SOIL_HEAT_FLUX_HOLLOW_10CM sensor had instrument malfunction on DOY 128 from 1400-600.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are frozen on DOYs 116 through 124, 126 and 129.
- SOIL_HEAT_FLUX_HOLLOW, all wet bulb temperatures, and all vapor pressures are missing DOY 98-131

Data Period: May 10 - May 23/94 (DOY 130-143)

- CO2_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM sensors installed on DOY 151 at 1800.
- SPECIFIC_HUMIDITY_450CM values are missing on DOYs 130 through 143.

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM values are missing on DOYs 130 from 1830-600, on DOY 131 from 630-1430, on DOY 132 from 2030-600, on DOY 133 from 630-600, on DOY 134 from 630-1630 and from 2030-600, on DOY 135 from 630-1500, and from 200-600, on DOY 136 from 630-1100 and from 1830-600, on DOY 137 from 630-1530 and from 1830-600, on DOY 138 from 630-1530 and from 2100-600, on DOY 139 from 630-1430, on DOY 140 from 1600-600 and on DOYs 141 through 143 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM values are missing on DOY 132 from 1600-1630 and on DOY 135 at 1630 due to instrument adjustment.
- SOIL_TEMPERATURE_HUMMOCK_50CM sensor was broken from DOYs 135 at 1600 through to 147 at 2100. Reinstalled on DOY 147 at 2130.
- WIND_SPEED_600CM sensor had incorrect offset from DOYs 131 through 142. Correct offset used on DOY 142 at 1500.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are frozen on DOYs 130 through 136, and 139-141.
- SOIL_HEAT_FLUX_HOLLOW, all wet bulb temperatures, and all vapor pressures are missing DOY 98-131.

Data Period: May 24 - June 6/94 (DOY 144-157)

- CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM sensors installed on DOY 151 at 1800.
- SPECIFIC_HUMIDITY_450CM values missing on DOYs 144 and 145.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM values are missing on DOY 144 from 630-1530.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 148 from 500-600, on DOY 149 from 630-600 and on DOY 150 from 630-600 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, and SPECIFIC_HUMIDITY_450CM values are missing on DOY 151 from 630-600 and on DOY 152 from 630-1530 due to weather.
- SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM values are missing on DOY 151 from 630-1730.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values missing on DOY 153 from 1500-2000 due to instrument replacement.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_MEAN_STDEV_450CM values are missing on DOY 153 from 2330-600 due to instrument failure.
- SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM values are missing on DOY 154 at 1930 due to lag tests.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, and SPECIFIC_HUMIDITY_450CM values are missing on DOY 157 from 450-600 due to weather.

- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOY 147.
- SOIL_TEMPERATURE_HUMMOCK_50CM sensor was broken from DOYs 135 at 1600 through to 147 at 2100. Reinstalled on DOY 147 at 2130.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are frozen on DOY 148.
- Changed hummock and hollow ground temperature rods on DOY 147 at approximately 2100.
- WET_BULB_TEMP_325CM sensor had a dry wick on DOY 155.
- WET_BULB_TEMP_400CM sensor had a dry wick on DOY 155.
- WET_BULB_TEMP_500CM sensor had a dry wick on DOY 156.
- DRY_BULB_TEMP_250CM sensor had inconsistent data on DOYs 155 and 156.
- DRY_BULB_TEMP_325CM sensor had inconsistent data on DOYs 154 and 156.
- DRY_BULB_TEMP_400CM sensor had inconsistent data on DOY 154.
- DRY_BULB_TEMP_600CM sensor had inconsistent data on DOYs 150 and 154.

Data Period: June 7 - June 20/94 (DOY 158-171)

- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, and SPECIFIC_HUMIDITY_450CM are missing on DOY 158 from 630-1200 due to instrument failure.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_STDEV_450CM values are missing on DOY 162 from 1600-600, on DOY 163 from 1530-600 and on DOY 164 from 630-1700 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, and SPECIFIC_HUMIDITY_450CM values are missing on DOY 162 from 630-1500 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 165 from 1130-600, on DOY 166 from 630-600, on DOY 167
- from 630-600, on DOY 168 from 630-1200, on DOY 169 from 330-600, on DOY 170 from 630-1630 and on DOY 171 from 730-600 due to instrument failure.
- CO2_CONC_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 165 from 1500-600 and on DOY 166 from 630-1600 due to weather.
- CO2_CONC_450CM values are missing on DOY 171 from 2030-600 due to weather.
- WET_BULB_TEMP_400CM sensor had a dry wick on DOY 169.
- WET_BULB_TEMP_750CM sensor had a dry wick on DOY 168.
- DRY_BULB_TEMP_400CM sensor had inconsistent data on DOYs 169 and 170.
- DRY_BULB_TEMP_600CM sensor had inconsistent data on DOY 170 and was rewicked on JDay 164 from 1800-2030.

Data Period: June 21 - July 4/94 (DOY 172-185)

- PPFD_OUT_1031CM sensor had instrument malfunctions on DOY 180 from 1900-600 and on DOY 181 from 1100-1400.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 174 from 2030-600 due to weather.

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 175 from 630-600, on DOY 176 from 630-1630, on DOY 177 from 1800-600, on DOY 178 from 630-1730, on DOY 179 from 100-600 and on DOY 180 from 630-1800 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM are missing on DOY 172 from 630-1800, on DOY 176 from 1700-600 and on DOY 177 from 630-1730, due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM are missing on DOY 180 from 200-600 and on DOY 184 from 1230-600 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM and CO2_TOTAL_FLUX_450CM are missing on DOY 172 from 2200-600 due to weather.
- SPECIFIC_HUMIDITY_450CM values are missing on DOY 172 from 400-600 due to weather.
- CO2_TOTAL_FLUX_450CM values are missing on DOY 179 from 1730-1900 due to instrument calibration.
- CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM values missing on DOYs 181 through 184 at 1200 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM and H2O_FLUX_450CM values are missing on DOY 184 at 630 due to instrument malfunction.
- SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 184 from 1700-600 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 185 from 630-600 due to instrument malfunction.
- SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED, PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_TEMP_HUMMOCK_1CM, SOIL_TEMP_HUMMOCK_5CM, SOIL_TEMP_HUMMOCK_10CM, SOIL_TEMP_HUMMOCK_25CM, SOIL_TEMP_HUMMOCK_50CM, SOIL TEMP_HUMMOCK_75CM, SOIL_TEMP_HUMMOCK_100CM, SOIL_TEMP_HUMMOCK_150CM, SOIL_TEMP_HUMMOCK_200CM, SOIL_TEMP_HOLLOW_1CM, SOIL_TEMP_HOLLOW_5CM, SOIL_TEMP_HOLLOW_10CM, SOIL_TEMP_HOLLOW_25CM, SOIL_TEMP_HOLLOW_50CM, SOIL_TEMP_HOLLOW_75CM, SOIL_TEMP_HOLLOW_100CM, SOIL_TEMP_HOLLOW_150CM, SOIL_TEMP_HOLLOW_200CM, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM,WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM, WET_BULB_TEMP_750CM, VAPOUR_PRESSURE_250CM, VAPOUR_PRESSURE_325CM, VAPOUR_PRESSURE_400CM, VAPOUR_PRESSURE_500CM, VAPOUR_PRESSURE_600CM, VAPOUR_PRESSURE_750CM, WIND_SPEED_250CM, WIND_SPEED_325CM, WIND_SPEED_400CM, WIND_SPEED_500CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM, RAINFALL_100CM and WATER_LEVEL_DEPTH values are missing on DOYs 181 at 1450 through to DOY 186 at 1530 due to loss of generator power.

- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_HUMMOCK_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOYs 181 through 185.
- WET_BULB_TEMP_600CM sensor had a dry wick on DOY 181.
- WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM,WET_BULB_TEMP_500CM, WET_BULB_TEMP_750CM had dry wicks from DOY 178 through to 180 at 1630.
- WET_BULB_TEMP_750CM and VAPOUR_PRESSURE_750CM sensors had data inconsistencies on DOY 175 from 1830-600 due to rewicking, and on DOYs 176 from 630-600 and 177 from 630-1900 due to instrument malfunctions.
- DRY_BULB_TEMP_400CM had data inconsistencies on DOYs 173 through 177.
- DRY_BULB_TEMP_750CM sensor had inconsistent data on DOY 175 from 1830-600 due to rewicking.
- WET_BULB_TEMP_325, 400, 500, and 600 had a dry wick on DOY 178

Data Period: July 5 - July 18/94 (DOY 186-199)

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOYs 186 through 189 at 1930, on DOY 193 from 2300-600, on DOY 194 from 630-600 and on DOY 195 from 630-1830 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 191 from 2030-600 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 192 from 630-1600 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 196 from 1300-1900 and from 300-600 and on DOY 197 from 630-1700 due to instrument malfunction.
- W_MEAN_450CM and W_MEAN_STDEV_450CM values are missing on DOY 192 at 1600.
- SOLAR_RAD_IN_1047M, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED, PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_TEMP_HUMMOCK_1CM, SOIL_TEMP_HUMMOCK_5CM, SOIL_TEMP_HUMMOCK_10CM, SOIL_TEMP_HUMMOCK_25CM, SOIL_TEMP_HUMMOCK_50CM, SOIL TEMP_HUMMOCK_75CM, SOIL_TEMP_HUMMOCK_100CM, SOIL_TEMP_HUMMOCK_150CM, SOIL_TEMP_HUMMOCK_200CM, SOIL_TEMP_HOLLOW_1CM, SOIL_TEMP_HOLLOW_5CM, SOIL_TEMP_HOLLOW_10CM, SOIL_TEMP_HOLLOW_25CM, SOIL_TEMP_HOLLOW_50CM, SOIL_TEMP_HOLLOW_75CM, SOIL_TEMP_HOLLOW_100CM, SOIL_TEMP_HOLLOW_150CM, SOIL_TEMP_HOLLOW_200CM, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM,WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM, WET_BULB_TEMP_750CM, VAPOUR_PRESSURE_250CM, VAPOUR_PRESSURE_325CM, VAPOUR_PRESSURE_400CM,

VAPOUR_PRESSURE_500CM, VAPOUR_PRESSURE_600CM, VAPOUR_PRESSURE_750CM, WIND_SPEED_250CM, WIND_SPEED_325CM, WIND_SPEED_400CM, WIND_SPEED_500CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM, RAINFALL_100CM and WATER_LEVEL_DEPTH values are missing on DOYs 181 at 1450 through to DOY 186 at 1530 due to loss of generator power.

- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_HUMMOCK_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOYs 186 and 193.
- WET_BULB_TEMP_325CM sensor had a dry wick on DOY 190.
- WET_BULB_TEMP_500CM sensor had a dry wick on DOYs 189, 190 and 195 through 198.
- WET_BULB_TEMP_600CM sensor had a dry wick on DOYs 186 through 192.
- DRY_BULB_TEMP_400CM had data inconsistencies on DOYs 191 and 192.

Data Period: July 19 - August 1/94 (Julian Days 200-213)

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on 201 from 630-2000 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, and SPECIFIC_HUMIDITY_450CM values are missing on DOY 200 from 1330-600 due to weather.
- CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 200 from 1800-600 due to weather.
- CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM values are missing on DOY 205 from 1530-1730, on DOY 207 from 030-200 and on DOY 213 from 1930-2230 due to instrument calibration.
- LATENT_HEAT_FLUX_450CM and H2O_FLUX_450CM values are missing on DOY 206 from 1200-1500 due to weather.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 203 from 1230-1450 and from 230-330 due to weather.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 211 from 1030-1130 due to instrument malfunction.
- SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED, PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_TEMP_HUMMOCK_1CM, SOIL_TEMP_HUMMOCK_5CM, SOIL_TEMP_HUMMOCK_10CM, SOIL_TEMP_HUMMOCK_25CM, SOIL_TEMP_HUMMOCK_50CM, SOIL TEMP_HUMMOCK_75CM, SOIL_TEMP_HUMMOCK_100CM, SOIL_TEMP_HUMMOCK_150CM, SOIL_TEMP_HUMMOCK_200CM, SOIL_TEMP_HOLLOW_1CM, SOIL_TEMP_HOLLOW_5CM, SOIL_TEMP_HOLLOW_10CM, SOIL_TEMP_HOLLOW_25CM, SOIL_TEMP_HOLLOW_50CM, SOIL_TEMP_HOLLOW_75CM, SOIL_TEMP_HOLLOW_100CM, SOIL_TEMP_HOLLOW_150CM, SOIL_TEMP_HOLLOW_200CM, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM, WET_BULB_TEMP_750CM,

VAPOUR_PRESSURE_250CM, VAPOUR_PRESSURE_325CM, VAPOUR_PRESSURE_400CM, VAPOUR_PRESSURE_500CM, VAPOUR_PRESSURE_600CM, VAPOUR_PRESSURE_750CM, WIND_SPEED_250CM, WIND_SPEED_325CM, WIND_SPEED_400CM, WIND_SPEED_500CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM, RAINFALL_100CM and WATER_LEVEL_DEPTH values are missing on DOYs 202 from 2030-2200 due to psychrometer work and on DOYs 211 from 2030-600 and DOY 212 from 630-1530 due to instrument repair.
- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on DOYs 202, 211 and 212.
- WET_BULB_TEMP_250CM sensor had a dry wick on DOY 204 and was subsequently rewicked.
- WET_BULB_TEMP_325CM sensor had a dry wick on DOYs 202, 203 and 204.
- WET_BULB_TEMP_600CM sensor had a dry wick on DOYs 201, 202, 203 through 207, and on 209.
- WET_BULB_TEMP_750CM sensor had a dry wick on DOYs 204 and 208.

Data Period: August 2 - August 15/94 (DOY 214-227)

- PPFD_OUT_1031CM sensor is broken on DOY 216 through 217 from 630-2230.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 214 from 1800-600 and on DOY 218 from 630-1730 due to weather.
- CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM values are missing on DOY 214 from 1600-600 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 215 from 630-1600 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 224 from 630-600 and on DOY 225 from 630-1600 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 217 from 2330-600, on DOY 218 from 630-1730 and on DOY 223 from 2200-600 due to weather.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 216 from 900-1230 due to instrument malfunction.
- WET_BULB_TEMP_600CM sensor had a dry wick on DOYs 221 through 227.

Data Period: August 16 - August 29/94 (DOY 228-241)

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, values are missing on DOY 234 from 130-600, on DOY 235 from 630-1530, on DOY 240 from 300-600, and on DOY 241 from 630-1730 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 240 from 630-1530 and on DOY 241 from 1800-600 due to weather.
- LATENT_HEAT_FLUX_450CM and H2O_FLUX_450CM values are missing on DOY 228 from 630-1130 due to instrument malfunction.

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 239 from 2200-600 due to weather.
- CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM values are missing on DOY 239 from 1730-600 due to weather.
- WET_BULB_TEMP_600CM sensor had a dry wick on DOYs 228 through 239.
- WET_BULB_TEMP_750CM sensor had a dry wick on DOY 240.
- DRY_BULB_TEMP_750CM sensor had data inconsistencies on DOY 240.

Data Period: August 30 - September 12/94 (DOY 242-255)

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 242 from 630-1450, due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 243 from 630-1330, on DOY 254 from 400-600 and on DOY 255 from 630-730 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 246 from 830-1300, on DOY 247 from 1400-600, and on DOY 248 from 630-1700 and from 2030-600 due to weather.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 244 from 900-1400 due to instrument malfunction.
- CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM values are missing on DOY 249 from 1730-600 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 249 from 2200-600 due to instrument malfunction.
- CO2_TOTAL_FLUX_450CM values are missing on DOY 250 from 530-630 and on DOY 251 from 630-800 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM and H2O_FLUX_450CM values are missing on DOY 251 at 630 due to instrument malfunction.
- WET_BULB_TEMP_500CM sensor had a dry wick on DOY 254
- WET_BULB_TEMP_600CM sensor had a dry wick on DOYs 245 through 255.
- WET_BULB_TEMP_750CM sensor had a dry wick on DOY 255.

Data Period: September 13 - September 19/94 (DOY 256-262)

- SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_10323M, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED, PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_TEMP_HUMMOCK_1CM, SOIL_TEMP_HUMMOCK_5CM, SOIL_TEMP_HUMMOCK_10CM, SOIL_TEMP_HUMMOCK_25CM, SOIL_TEMP_HUMMOCK_50CM, SOIL TEMP_HUMMOCK_75CM, SOIL_TEMP_HUMMOCK_100CM, SOIL_TEMP_HUMMOCK_150CM, SOIL_TEMP_HUMMOCK_200CM, SOIL_TEMP_HOLLOW_1CM, SOIL_TEMP_HOLLOW_5CM, SOIL_TEMP_HOLLOW_10CM, SOIL_TEMP_HOLLOW_25CM, SOIL_TEMP_HOLLOW_50CM, SOIL_TEMP_HOLLOW_75CM, SOIL_TEMP_HOLLOW_100CM, SOIL_TEMP_HOLLOW_150CM, SOIL_TEMP_HOLLOW_200CM, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM,

WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM, WET_BULB_TEMP_750CM, VAPOUR_PRESSURE_250CM, VAPOUR_PRESSURE_325CM, VAPOUR_PRESSURE_400CM, VAPOUR_PRESSURE_500CM, VAPOUR_PRESSURE_600CM, VAPOUR_PRESSURE_750CM, WIND_SPEED_250CM, WIND_SPEED_325CM, WIND_SPEED_400CM, WIND_SPEED_500CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM, RAINFALL_100CM and WATER_LEVEL_DEPTH values are missing on DOY 262 from 1500-600 (end of field season).

- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 256 from 630-1700 and on DOY 258 from 2200-600 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 258 on 630-1700 and on DOY 259 from 630-600, on DOY 260 from 630-1530 and from 2200-600 and on DOY 261 from 630-1530 due to instrument malfunction.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM and SPECIFIC_HUMIDITY_450CM values are missing on DOY 256 from 1800-1830 due to instrument calibration.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 257 from 1530-1730 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_TOTAL_FLUX_450CM, CO2_CONC_450CM, SPECIFIC_HUMIDITY_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, W_MEAN_450CM and W_MEAN_STDEV_450CM are missing on DOY 262 from 1530-600 due to the end of the field season.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM values are missing on DOY 257 from 900-1300 due to weather.
- SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_HOLLOW_10CM, SOIL_HEAT_FLUX_FEN, HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR values are missing on 262 (end of field season).
- DRY_BULB_TEMP_500CM sensor had inconsistent data on DOY 261.

SPECIAL NOTES: 1995

All data were averaged over thirty minutes, starting on the hour and half-hour, and ending thirty minutes later. Sampling was continuous and each day's data is from 0600 UTC to 0600 UTC the next day.

- LONGWAVE_IN_1033CM was calculated as a residual.
- Small nighttime values for SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, PPFD_IN_1049CM, and PPFD_OUT_1031CM were set to zero to account for very slight zero depressions and elevations in the radiometers.
- R_NET_1035CM_CORRECTED was calculated from day and night time equations developed by Hodges and Smith (1997) (see documentation for details).
- HEAT_STORAGE_TOTAL is the sum of HEAT_STORAGE_LATENT_AIR, HEAT_STORAGE_SENSIBLE_AIR, and SOIL_HEAT_FLUX_HOLLOW_10CM

Data Period: April 8 - April 11/95 (DOY 098-101)

- R_NET_1035CM sensor installed on DOY 098 at 1830.
- WIND_SPEED_250CM sensor installed on DOY 098 at 2000.
- WIND_SPEED_325CM sensor installed on DOY 098 at 2030.
- WIND_SPEED_400CM and WIND_SPEED_500CM sensors installed on DOY 098 at 2100.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, and DRY_BULB_TEMP_400CM sensors installed on DOY 099 at 2000.
- SOLAR_RAD_IN_1047CM and SOLAR_RAD_OUT_1023CM sensors installed on JDay 099 at 2000.
- LONGWAVE_RAD_OUT_1033CM sensor installed on DOY 099 at 2200.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM not installed until DOY 100 at 630.
- WIND_SPEED_600CM, WIND_DIR_600CM and WIND_DIR_STDEV_600CM sensors installed on DOY 100 at 2200.
- PPFD_IN_1049CM and PPFD_OUT_1031CM sensors installed on DOY 101 at 2000.
- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are intermittently frozen on DOYs 098 through 101.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM are missing on DOY 101 from 1630 to 1930 due to programming error.

Data Period: April 12 - April 25/95 (DOY 102-115)

- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are intermittently frozen on DOYs 102 through 115.
- SENSIBLE_HEAT_FLUX_450CM value is missing on DOY 116 from 130 to 600 due to broken thermocouple wire.

Data Period: April 25 - May 9/95 (DOY 116-129)

- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are intermittently frozen on DOYs 116 through 129.
- SOIL_HEAT_FLUX_HOLLOW_10CM installed on DOY 127 at 1600.
- SENSIBLE_HEAT_FLUX_450CM value is missing on DOYs 116 through 124 at 1430 due to a broken thermocouple wire.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM are missing on DOY 116 at 1330 through DOY 118 at 1530.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM are missing on DOY 130 from 230-430 due to ice on the hygrometer.

Data Period: May 10 - May 23/95 (DOY 130-143)

- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are intermittently frozen on DOYs 130 through 138 and 143.
- PPFD_IN_1049CM sensor has intermittent open circuit from DOY 136 through 142.
- PPFD_IN_1033CM sensor has open circuit on DOY 143.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM and SPECIFIC_HUMIDITY_450CM are missing on DOY 130 from 830 through 1300 due to ice on the hygrometer.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM and H2O_FLUX_450CM are missing on DOY 130 at 1330 to 131 at 1830 due to weather.
- LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM readings end on DOY 132 at 1930.

Data Period: May 24 - June 6/95 (DOY 144-157)

- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are intermittently frozen on DOY 144 through 145 and on DOY 147.
- PPFD_IN_1049CM sensor has open circuit on from DOY 144 through 157.

Data Period: June 7 - June 14/95 (DOY 158-165)

- DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_325CM, DRY_BULB_TEMP_400CM, DRY_BULB_TEMP_500CM, DRY_BULB_TEMP_600CM, DRY_BULB_TEMP_750CM, WET_BULB_TEMP_250CM, WET_BULB_TEMP_325CM, WET_BULB_TEMP_400CM, WET_BULB_TEMP_500CM, WET_BULB_TEMP_600CM and WET_BULB_TEMP_750CM sensors are intermittently frozen on DOY 158 through 161.
- PPFD_IN_1049CM sensor has open circuit on from DOY 158 through 165.

Data Period: April 29 - May 8\96 (DOY 120-129)

- SOIL_HEAT_FLUX_HOLLOW_10CM sensor not installed until DOY 133 at 2230 due to
- frozen ground conditions.
- WIND_SPEED_400CM not available until DOY 189 at 0630.
- SOIL_TEMPERATURE_HUMMOCK_50CM not available from DOY 123(1430) to DOY 132(1730).
- HEAT_STORAGE_TOTAL, and HEAT_STORAGE_LATENT_AIR not available until 134(1700).
- HEAT_STORAGE_SENSIBLE_AIR not available until DOY 133(0630).
- DOY 120(1600) CO2_EDDY_FLUX_450CM and CO2_CONC_450CM were linearly interpolated.
- DOY 122 CO2_EDDY_FLUX_450CM(2000), and CO2_CONC_450CM(1730) were linearly interpolated.
- DOY 123(1700-1900,2030) CO2_CONC_450CM(1700-1900), and CO2_EDDY_FLUX_450CM
- were linearly interpolated.
- DOY 126(1700) and 129(1500-1530) CO2_CONC_450CM and CO2_EDDY_FLUX_450CM were linearly interpolated.

- DOY 120 (0630-1600) LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_STORAGE_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, and VAPOUR_PRESSURE_400CM are not available.
- DOY 126(2130) to 129(1500) LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_EDDY_FLUX_450CM, and CO2_TOTAL_FLUX_450CM not available.
- SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM missing DOY127(1800-2300).

SPECIAL NOTES: 1996

All data were averaged over thirty-minute intervals, starting on the hour or half-hour, and ending thirty minutes later. Sampling was continous, and each day's data is from 0600 UTC to 0600 UTC the next day.

- LONGWAVE_IN_1033CM was calculated as a residual.
- Small nighttime values for SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, PPFD_IN_1049CM, and PPFD_OUT_1031CM were set to zero to account for very slight zero depressions and elevations in the radiometers.
- Negative values of NET_SOLAR_RAD_1035CM were set to zero, as were corresponding values of SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, and SURFACE_ALBEDO.
- Corresponding changes were also made in the calculations of LONGWAVE_IN_1033CM, TOTAL_RAD_IN_1041CM, and TOTAL_RAD_OUT_1028CM.
- R_NET_1035CM_CORRECTED was calculated from day and night time equations developed by Hodges and Smith(1997) (see documentation for details).
- LATENT_HEAT_FLUX_450CM is flagged if <-50.00 W/m^2.
- SENSIBLE_HEAT_FLUX_450CM is flagged if <-70.00 W/m^2.
- HEAT_STORAGE_TOTAL is the sum of HEAT_STORAGE_SENSIBLE_AIR, HEAT_STORAGE_LATENT_AIR, and SOIL_HEAT_FLUX_HOLLOW_10CM.
- CO2_TOTAL_FLUX_450CM is the sum of CO2_EDDY_FLUX_450CM, and CO2_STORAGE_FLUX_450CM.
- Where only CO2_STORAGE_FLUX_450CM is missing, CO2_TOTAL_FLUX_450CM is based on CO2_EDDY_FLUX_450CM only.
- When SOLAR_RAD_IN_1047CM is zero, any negative CO2_TOTAL_FLUX_450CM values are set to zero as well.

Data Period: May 9 - May 22\96 (DOY 130-143)

- SOIL_HEAT_FLUX_HOLLOW_10CM sensor not installed until DOY 133 at 2230 due to frozen ground conditions.
- WIND_SPEED_400CM not available until DOY 189 at 0630.
- SOIL_TEMPERATURE_HUMMOCK_50CM not available from DOY 123(1430) to DOY 132(1730).
- HEAT_STORAGE_TOTAL, and HEAT_STORAGE_LATENT_AIR not available until 134(1700).
- HEAT_STORAGE_SENSIBLE_AIR not available until DOY 133(0630).
- DOY 135(1430-1500) and 136(1930-2000) CO2_EDDY_FLUX_450CM and CO2_CONC_450CM are linearly interpolated.
- DOY 132 (1600-1730) SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1028CM, TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED,PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, all soil temperatures in the hummock and hollow, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_600CM, WIND_DIR_600CM, and WIND_DIR_STDEV_600CM missing due to processing problems.

- DOY 132(1830) to 134(1630) LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, CO2_TOTAL_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, SPECIFIC_HUMIDITY_STDEV_450CM, VAPOUR_PRESSURE_400CM, W_MEAN_450CM, W_STDEV_450CM, RELATIVE_HUMIDITY_400CM, AIR_PRESSURE, and CO2_CONC_450CM missing due to processing malfunctions.
- LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM (137 1600-152 0500), SENSIBLE_HEAT_FLUX_450CM (137 1600-152 2000), CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, and CO2_TOTAL_FLUX_450CM (137 1300-155 1800)are missing.
- DOY 132(1800), 134(1700), and 137(1300) CO2_STORAGE_FLUX_450CM are missing.
- SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM is unavailable from DOY 139(1030-1400) and DOY 139(1730) to 142(1300).

Data Period: May 23 - June 5\96 (DOY 144-157)

- WIND_SPEED_400CM not available until DOY 189 at 0630.
- LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM (137 1600-152 0500), SENSIBLE_HEAT_FLUX_450CM (137 1600-152 2000), CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, and CO2_TOTAL_FLUX_450CM (137 1300-155 1800) are missing.
- DOY 155(1800-1830) sign of CO2_TOTAL_FLUX_450CM is corrected.
- SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM unavailable DOY 152 (1200-1400), 152(1700) to 153(1700), 153(0700) to 154(1830), and 156(0500) to 157(1330).
- LATENT_HEAT_FLUX_450CM and H2O_FLUX_450CM unavailable DOY 153(0700) to 154(0830), and 156(0500) to 157(1330).
- DOY 158(2100)-160(0630) CO2_CONC_450CM is missing.

Data Period: June 6 - June 19\96 (DOY 158-171)

- WIND_SPEED_400CM not available until DOY 189 at 0630.
- LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM unavailable DOY 158(2100)-159(1830), 161(0400-1400), 162(1530-1900), 164(0730-1500), 165(1700-1900), 166(0500)-167(2130), and 167(0400)-168(1130).
- SENSIBLE_HEAT_FLUX_450CM unavailable DOY 158(2100)-159(1830), and 165(1700-1900).
- CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, and CO2_TOTAL_FLUX_450CM are unavailable DOY 158(2100)-160(0630),and 165(1700-1900).
- CO2_STORAGE_FLUX_450CM is missing DOY 158(2030), 160(0630), and 165(1630,1930).
- SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM unavailable DOY 160(0400)-161(1400), 162(1530-1900), 164(0730-1500), 166(0500)-167(2130), 167(0400)-168(1130).

Data Period: June 20 - July 3\96 (DOY 172-185)

- WIND_SPEED_400CM not available until DOY 189 at 0630.
- DOY 180(1530)-189(0630) SOIL_TEMPERATURE_HUMMOCK_50CM is unavailable.
- Linear interpolation of CO2_CONC_450CM occurred DOY 176(1800-1930), 177(1900), 179(1730-1800),and 185(1530) and CO2_TOTAL_FLUX_450CM DOY 176(1800-2030), 177(1900), 179(1730-1800), and 185(1530).
- DOY 172 (0900-2230) SENSIBLE_HEAT_FLUX_450CM, CO2_EDDY_FLUX_450CM, and CO2_TOTAL_FLUX_450CM are unavailable.

- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM missing at following times: DOY 171(0430)-173(1800), 174(1100-1400), 181(0230)-182(1430), 182(0400)-183(1500), 185(0730-1230), 185(0430)-186(1630).
- DOY 180 HEAT_STORAGE_TOTAL, HEAT_STORAGE_SENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR is unavailable.
- DOY 180 (0030-0600) SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM, TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED,PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO,SOIL_HEAT_FLUX_HOLLOW_10CM, all hummock and hollow temperatures, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_600CM, WIND_SPEED_250CM, WIND_SPEED_600CM, WIND_DIR_600CM,WIND_DIR_STDEV_600CM, and RAINFALL_100CM are unavailable.

Data Period: July 4 - July 17\96 (DOY 186-199)

- WIND_SPEED_400CM not available until DOY 189 at 0630.
- DOY 180(1530)-189(0630) SOIL_TEMPERATURE_HUMMOCK_50CM is unavailable.
- DOY 185(0430)-186(1630) LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM are missing.
- SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM, TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, R_NET_1035CM_CORRECTED,PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_HEAT_FLUX_HUMMOCK_10CM, SOIL_HEAT_FLUX_HOLLOW_10CM, all soil temperatures for both hummock and hollow, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_600CM, WIND_SPEED_250CM, WIND_SPEED_400CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM,and RAINFALL_100CM unavailable DOY 189(1530-1700),189(0500)-190(1200), and 190(1630-1830) and linearly interpolated DOY 189 (1800-1830, 2300-2330, 0030,0130,0300,0400), DOY 190(1300 - except for RAINFALL_100CM, WIND_DIR_600CM, and WIND_DIR_STDEV_600CM).
- SOIL_TEMPERTURE_HUMMOCK_1CM linearly interpolated DOY 193(2000).
- Linear interpolation of CO2_CONC_450CM and CO2_TOTAL_FLUX_450CM occurred DOY 187(1800), 193(1730-1800,1930),196(1800), and 199(2100).
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM unavailable DOY 188(1100)-189(1330), 198(1930-2200),198(2330-0630).

Data Period: July 18 - July 31\96 (DOY 200-213)

- SOIL_TEMPERATURE_HUMMOCK_1CM linearly interpolated DOY 202(2200), 209(2030,2100), 212(2000, 2030).
- Linear interpolation of CO2_CONC_450CM DOY 202(2100-2200), 207(1730-1930), 209(1930) and 212(2130) and CO2_TOTAL_FLUX_450CM DOY 202(2000-2200), 207(1930), 209(1930),and 212(2130).
- AIR_PRESSURE linearly interpolated DOY 202(2100, 2130), 207(1730-1900).
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM missing on the following days: DOY 201(0730-1130), 202(0630-1630), and 203(0730-1300).
- DOY 202(1900-2130) LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM is missing.
- SOIL_TEMPERATURE_HUMMOCK_50CM is missing DOY 203(1830)-209(2100), 212(2100)-217(2000).

Data Period: August 1 - August 14\96 (DOY 214-227)

- DOY 214(2000) AIR_PRESSURE linearly interpolated.
- DOY 214(2000), 217(2100), 221(1830-1930), 226(2030) CO2_CONC_450CM is linearly interpolated.
- DOY 220 SOIL_TEMPERATURE_HUMMOCK_1CM (1830-2030) and SOIL_TEMPERATURE_HOLLOW_10CM (2000) linearly interpolated.
- DOY 224(1530) linearly interpolated SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1035CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM, TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, PPDF_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO, SOIL_HEAT_FLUX_HUMMOCK_10CM, SOIL_HEAT_FLUX_HOLLOW_10CM, all soil temperatures for both hummock and hollow, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_600CM, WIND_SPEED_250CM, WIND_SPEED_400CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM, and RAINFALL_100CM. These variables are also missing DOY 224(1830-2100).
- DOY 226(2030)AIR_PRESSURE and RELATIVE_HUMIDITY_400CM is linearly interpolated.
- DOY 226(1930-2030) CO2_TOTAL_FLUX_450CM is linearly interpolated.
- DOY 214(630)-224(2130) WIND_SPEED_400CM is missing.
- DOY 214(1800-2130) LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM are missing.
- DOY 214(1800-2030) SENSIBLE_HEAT_FLUX_450CM, CO2_EDDY_FLUX_450CM, and CO2_TOTAL_FLUX_450CM are missing.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM are unavailable DOY 215(1000-1330) 218(2030-2300), 219(1300-2230), 219(0200-0700), 220(1000-1300, 1600-1830), 220(0400)-221(1530), 222(1430-2100), 223(0930-1530), 223(0200)-224(1400).
- DOY 226(2030)-233(1300) LATENT_HEAT_FLUX_450CM is missing.
- DOY 226(2030)-233(0630) SENSIBLE_HEAT_FLUX_450CM is missing.
- SOIL_TEMPERATURE_HUMMOCK_50CM is missing 214(0630)-217(2000), 220(2200)-221(2100)
- SOIL_TEMPERATURE_HOLLOW_5CM is missing DOY217(2000)-218(2000), 218(1930)-220(2000)
- DOY 223(1800-2330) WIND_DIR_600CM, WIND_DIR_STDEV_600CM are missing.
- HEAT_STORAGE_TOTAL, HEAT_STORAGE_SSENSIBLE_AIR, and HEAT_STORAGE_LATENT_AIR are missing DOY 224
- H2O_FLUX_450CM unavailable DOY 227(0630-1200), 227(0230-0530).

Data Period: August 15 - August 28\96 (DOY 228-241)

- DOY 226(2030)-233(1300) LATENT_HEAT_FLUX_450CM is missing.
- DOY 226(2030)-233(0630) SENSIBLE_HEAT_FLUX_450CM is missing.
- CO2_EDDY_FLUX_450CM, and CO2_CONC_450CM are linearly interpolated on DOY 238(1830), 239(1930), and 241(1930).
- DOY 236(1930-2000) CO2_CONC_450CM is linearly interpolated.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, CO2_EDDY_FLUX_450CM, CO2_TOTAL_FLUX_450CM unavailable DOY 233(0530)-234(1200), 237(900-1330), 237(2000)-238(1500), 238(0530)-239(1300).
- H2O_FLUX_450CM unavailable 227(0630-1200), 227(0230-0530), 228(0370-1200), 228(0100)-229(1830), 229(0100)-233(1300)
- DOYs 230, 231, and 232 CO2_STORAGE_FLUX_450CM, CO2_CONC_450CM, HEAT_STORAGE_TOTAL, HEAT_STORAGE_LATENT_AIR, VAPOUR_PRESSURE_400CM, W_MEAN_450CM, W_STDEV_450CM, RELATIVE_HUMIDITY, AND AIR_PRESSURE are unavailable.

- DOY 236(1830-2100) CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, and CO2_TOTAL_FLUX_450CM is unavailable.
- SPECIFIC_HUMIDITY and SPECIFIC_HUMIDITY_STDEV are missing DOY 228(0100)-229(1800), 230(0630)-233(1300), 233(0530)-234(1200), 237(0900-1330), 237(2000)-238(1500), 238(0530)-239(1300)
- WIND_DIR_600CM, and WIND_DIR_STDEV_600CM are missing DOY 223(1800-2330), 228(2000-2300), 233(1900-2130), 234(0130)-242(1830).

Data Period: August 29 - September 11\96 (DOY 242-255)
- DOY 244(1130-2000) LATENT_HEAT_FLUX_450CM, and H2O_FLUX_450CM, are unavailable.
- DOY 249(1830)-255(1600) LATENT_HEAT_FLUX_450CM, SENSIBLE_HEAT_FLUX_450CM, and H2O_FLUX_450CM are unavailable.
- DOY 249(1830)-258(1800) CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, CO2_TOTAL_FLUX_450CM, and CO2_CONC_450CM are unavailable.
- DOY 248(1600)-248(0230) WIND_DIR_600CM, and WIND_DIR_STDEV_600CM are unavailable
- SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM are unavailable DOY 244(1130-2000), 249(0430-0800), 250(0930-0100), 251(0500)-252(1330), 253(1200-1500, 1600-2030), 253(0100)-255(1530).
- Due to power supply problems, SOLAR_RAD_IN_1047CM, SOLAR_RAD_OUT_1023CM, NET_SOLAR_RAD_1023CM, LONGWAVE_IN_1033CM, LONGWAVE_OUT_1033CM, TOTAL_RAD_IN_1041CM, TOTAL_RAD_OUT_1028CM, R_NET_1035CM, PPFD_IN_1049CM, PPFD_OUT_1031CM, SURFACE_ALBEDO unavailable DOY 250(0230)-258(1800), and SOIL_HEAT_FLUX_HUMMOCK_10CM, SOIL_HEAT_FLUX_HOLLOW_10CM, all soil hummock and hollow temperatures, DRY_BULB_TEMP_250CM, DRY_BULB_TEMP_600CM, WIND_SPEED_250CM, WIND_SPEED_400CM, WIND_SPEED_600CM, WIND_DIR_600CM, WIND_DIR_STDEV_600CM, and RAINFALL_100CM are unavailable DOY 250(0230)-259(0630), and HEAT_STORAGE_TOTAL, HEAT_STORAGE_LATENT_AIR, and HEAT_STORAGE_SENSIBLE_AIR are unavailable DOYs 250 to 258.

Data Period: September 12 - September 25\96 (DOY 256-269)
- DOY 261(1830), and 264(1930-2000) CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM are linearly interpolated.
- DOY 267(1730) CO2_CONC_450CM is linearly interpolated.

Data Period: September 26 - October 9\96 (DOY 270-282)
- CO2_TOTAL_FLUX_450CM and CO2_CONC_450CM are linearly interpolated on the following days: 270(2000), 273(1930), 276(1730), 278(1730-1800), 279(1730), 281(0800-0900), and 282(0630-0700).
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM are unavailable at the following times: DOY270(0130)-271(0800), 271(0930-1330), 271(2300-0400), 272(1600-1900), 281(2230)-282(1830).

Data Period: October 10 - October 23\96 (DOY 283-297)
- CO2_EDDY_FLUX_450CM, and CO2_CONC_450CM are linearly interpolated DOY 283(2130), 289(1730-1800), 291(1730), 292(2000), 293(0500-0530), 295(1630), 297(1830).
- CO2_EDDY_FLUX_450CM is linearly interpolated DOY294(0730, 1230, 1530-1830).
- CO2_EDDY_FLUX_450CM, and CO2_TOTAL_FLUX_450CM are missing DOY 286(2130-2200), 287(0700-1800, 0130-0530), 28990700-1500), 289(1630-1730),

296(0900-1100).

- DOY 286(0900-1530) CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, and CO2_TOTAL_FLUX_450CM is unavailable.
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, SPECIFIC_HUMIDITY_450CM, and SPECIFIC_HUMIDITY_STDEV_450CM are unavailable DOY 284(1600)-285(1100), 286(0900-1930), 286(0130)-287(1800), 287(0130)-288(0100), 288(0250)-289(2130), 293(0330-1630), 296(2100-2330).
- SENSIBLE_HEAT_FLUX_450CM is unavailable DOY 286(0900-1530), 287(0700-1800), 287(0130-0530), 289(0700-1500).
- WIND_DIR_600CM, and WIND_DIR_STDEV_450CM are unavailable DOY 290(0700-1130), 291(0030)-292(1630), 293(2200)-294(1730), 294(0200-0500), 295(0630-1700), 296(2330)-297(1500).
- W_MEAN_450CM, and W_MEAN_STDEV_450CM are missing DOy 287(0700-1800), and 287(0130-0430).
- RAINFALL_100CM is missing DOY 283(2230)-310(0600).

Data Period: October 24 - November 5\96 (DOY 298-310)

- DOY 300(2000), 303(1700) CO2_TOTAL_FLUX_450CM is linearly interpolated.
- RAINFALL_100CM is missing DOY 283(2230)-310(0600).
- LATENT_HEAT_FLUX_450CM, H2O_FLUX_450CM, are unavailable DOY 298(0230)-301(1900), 301(0200)-303(1400),303(1830-0300), 306(1730)-307(1600), 308(2330)-309(1800), and 309(0330)-310(0600).
- SENSIBLE_HEAT_FLUX_450CM is unavailable DOY 303(2000-0300), 306(1730)-307(1600), 308(2330)-309(1800).
- CO2_EDDY_FLUX_450CM and CO2_TOTAL_FLUX_450CM are missing DOY 302(1730-1800, 2230-2300), 303(2000-0300), 306(1730)-307(1600), 307(0330-0430), and 308(2330)-309(1800).
- CO2_EDDY_FLUX_450CM, CO2_STORAGE_FLUX_450CM, and CO2_TOTAL_FLUX_450CM are missing DOY 305(1830-1930).
- SPECIFIC_HUMIDITY_450CM and SPECIFIC_HUMIDITY_STDEV_450CM are unavailable DOY 298(0230)-299(1900), 299(2100)-301(1900), 301(0200)-303(1430), 306(0330)-307(0730), 309(0830-1530), 309(0330)-310(0600).
- WIND_SPEED_250CM, and WIND_SPEED_600CM are unavailable DOY 301(0800-1630).
- WIND_DIR_600CM and WIND_DIR_STDEV_600CM are unavailable DOY 301(0830-1500), 302(0930-1530), 302(0230)-303(1830), 306(1700)-308(1100), 309(0730-1930), 310(1100-0600).
- W_MEAN_450CM, and W_MEAN_STDEV_450CM are unavailable DOY 303(2300-0300), 306(1730)-307(1330), 308(2330)-309(1800)
- All variables are missing DOY 310(1730-0600) due to the shut-down of power.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

All data were collected at the BOREAS NSA fen site. North American Datum of 1983 (NAD83) coordinates for the site are latitude 55.91481 °N, longitude 98.42072 °W, and elevation of 211.33 m.

The fen site is located along Hwy. 391 west of Thompson, Manitoba. The fen site is located approximately 9 km to the west of the YJP site. The fen is located in a natural depression, and the fetch is limited to the east of the tower, where the forested shore is located 150 m from the tower. Cold-air drainage at night could be a factor at this site.

Most of the micrometeorological data were collected on the flux towers at the fen. The soil heat flux, biomass temperatures, and rainfall data were collected in the immediate vicinity of the flux towers. All of the micrometeorological data not collected on the towers were measured more than 30 m away from the towers. Global Positioning System (GPS) location coordinates are available for all sample locations on each site.

7.1.2 Spatial Coverage Map

Not applicable.

7.1.3 Spatial Resolution

The data collected from towers are usually thought of as point data. However, they actually represent an integrated response to the surface/atmosphere interaction, especially in terms of the eddy flux data, which are considered to represent an integrated upwind surface source region (Leclerc and Thurtell, 1990; Schmid and Oke, 1990). In general, at the YJP the fluxes apply to the surface between 20 to 400 meters upwind. At the fen, where fetch in certain wind directions is limited, data uncertainties may occur (see Section 10.1).

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The start and stop times for the experiments were as follows:

15-AUG-1993 to 31-AUG-1993
10-APR-1994 to 19-SEP-1994
15-APR-1995 to 10-JUN-1995
25-APR-1996 to 10-NOV-1996

7.2.2 Temporal Coverage Map

Not applicable.

7.2.3 Temporal Resolution

With one exception, the data values submitted to BORIS were integrations of the conditions for the 30-minute reporting periods.

Meteorological data were output at 15- and 30-minute intervals depending upon the variable. The 15-minute data included only absolute wet- and dry-bulb air temperatures and soil temperatures, which were used for heat storage calculations (described below). All signals, except temperature differences, were averaged over 30-minute periods. Only the 30-minute data were reported to BORIS. Eddy covariance data were output every 30 minutes.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

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         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
SENSIBLE_HEAT_FLUX_ABV_CNPY
LATENT_HEAT_FLUX_ABV_CNPY
NET_RAD_ABV_CNPY
CO2_FLUX_ABV_CNPY
CO2_CONC_ABV_CNPY
CO2_STORAGE
CO2_FLUX_ABV_PLUS_STORAGE
DOWN_PPFD_ABV_CNPY
UP_PPFD_ABV_CNPY
WIND_SPEED_250CM
WIND_SPEED_325CM
WIND_SPEED_359CM
WIND_SPEED_400CM
WIND_SPEED_465CM
WIND_SPEED_500CM
WIND_SPEED_575CM
WIND_SPEED_655CM
WIND_SPEED_765CM
WIND_SPEED_ABV_CNPY
MEAN_WIND_DIR_MAG_ABV_CNPY
SDEV_WIND_DIR_MAG_ABV_CNPY
AIR_TEMP_ABV_CNPY
H2O_FLUX_ABV_CNPY
SOIL_HEAT_FLUX_HUMMOCK_10CM
SOIL_HEAT_FLUX_HOLLOW_10CM
SOIL_HEAT_FLUX_FEN
SOIL_TEMP_HUMMOCK_1CM
SOIL_TEMP_HUMMOCK_5CM
SOIL_TEMP_HUMMOCK_10CM
SOIL_TEMP_HUMMOCK_25CM
SOIL_TEMP_HUMMOCK_50CM
SOIL_TEMP_HUMMOCK_75CM
SOIL_TEMP_HUMMOCK_100CM
SOIL_TEMP_HUMMOCK_150CM
SOIL_TEMP_HUMMOCK_200CM
SOIL_TEMP_HOLLOW_1CM
SOIL_TEMP_HOLLOW_5CM
SOIL_TEMP_HOLLOW_10CM
SOIL_TEMP_HOLLOW_25CM
SOIL_TEMP_HOLLOW_50CM
SOIL_TEMP_HOLLOW_75CM
SOIL_TEMP_HOLLOW_100CM
SOIL_TEMP_HOLLOW_150CM
SOIL_TEMP_HOLLOW_200CM
RAINFALL
DOWN_SOLAR_RAD_ABV_CNPY
```

UP_SOLAR_RAD_ABV_CNPY
NET_SOLAR_RAD_ABV_CNPY
UP_TOTAL_RAD_ABV_CNPY
AIR_TEMP_250CM
AIR_TEMP_257CM
AIR_TEMP_325CM
AIR_TEMP_359CM
AIR_TEMP_400CM
AIR_TEMP_465CM
AIR_TEMP_500CM
AIR_TEMP_575CM
AIR_TEMP_600CM
AIR_TEMP_655CM
AIR_TEMP_765CM
WET_BULB_TEMP_250CM
WET_BULB_TEMP_257CM
WET_BULB_TEMP_325CM
WET_BULB_TEMP_359CM
WET_BULB_TEMP_400CM
WET_BULB_TEMP_465CM
WET_BULB_TEMP_500CM
WET_BULB_TEMP_575CM
WET_BULB_TEMP_600CM
WET_BULB_TEMP_655CM
WET_BULB_TEMP_765CM
WET_BULB_TEMP_ABV_CNPY
VAPOR_PRESS_250CM
VAPOR_PRESS_257CM
VAPOR_PRESS_325CM
VAPOR_PRESS_359CM
VAPOR_PRESS_400CM
VAPOR_PRESS_465CM
VAPOR_PRESS_500CM
VAPOR_PRESS_575CM
VAPOR_PRESS_600CM
VAPOR_PRESS_655CM
VAPOR_PRESS_765CM
VAPOR_PRESS_ABV_CNPY
SURF_PRESS
WATER_TABLE_HGT
DOWN_LONGWAVE_RAD_ABV_CNPY
UP_LONGWAVE_RAD_ABV_CNPY
DOWN_TOTAL_RAD_ABV_CNPY
CORR_NET_RAD_ABV_CNPY
ALBEDO
TOTAL_HEAT_STORAGE
SENSIBLE_AIR_HEAT_STORAGE
LATENT_AIR_HEAT_STORAGE
MEAN_SPECIFIC_HUM_ABV_CNPY
SDEV_SPECIFIC_HUM_ABV_CNPY
MEAN_W_WIND_SPEED_ABV_CNPY
SDEV_W_WIND_SPEED_ABV_CNPY
REL_HUM_ABV_CNPY
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) of the start of the data collection.
SENSIBLE_HEAT_FLUX_ABV_CNPY	The sensible heat flux measured above the canopy. Instrument heights: in 1993 at 6 m, 1994 and 1996 at 4.5 m.
LATENT_HEAT_FLUX_ABV_CNPY	The latent heat flux measured above the canopy. Instrument heights: in 1993 at 6 m, 1994 and 1996 at 4.5 m.
NET_RAD_ABV_CNPY	The net radiation measured above the canopy, in 1993, 1994, and 1996 at 10.35 m height.
CO2_FLUX_ABV_CNPY	The carbon dioxide flux measured above the canopy Instrument heights: in 1994 and 1996 at 4.5 m
CO2_CONC_ABV_CNPY	The carbon dioxide concentration measured above the canopy. Instrument heights: in 1994 and 1996 at 4.5 m.
CO2_STORAGE	The storage term of carbon dioxide under the eddy flux system.
CO2_FLUX_ABV_PLUS_STORAGE	The sum of the above canopy carbon dioxide flux and the under flux instrument storage term.
DOWN_PPFD_ABV_CNPY	The downward (incoming) photosynthetic photon flux density measured above the canopy. In 1993, 1994, and 1996 at 10.49 m height
UP_PPFD_ABV_CNPY	The reflected photosynthetic photon flux density measured above the canopy. In 1993, 1994, and 1996 at 10.31 m height
WIND_SPEED_250CM	The wind speed measured 2.5 m above the ground.
WIND_SPEED_325CM	The wind speed measured 3.25 m above the ground.
WIND_SPEED_359CM	The wind speed measured 3.59 m above the ground.
WIND_SPEED_400CM	The wind speed measured 4 m above the ground.
WIND_SPEED_465CM	The wind speed measured 4.65 m above the ground.
WIND_SPEED_500CM	The wind speed measured 5 m above the ground.
WIND_SPEED_575CM	The wind speed measured 5.75 m above the ground.
WIND_SPEED_655CM	The wind speed measured 6.55 m above the ground.
WIND_SPEED_765CM	The wind speed measured 7.65 m above the ground.
WIND_SPEED_ABV_CNPY	The wind speed measured above the canopy, in

	1994 and 1996 at 6 m height.
MEAN_WIND_DIR_MAG_ABV_CNPY	The average wind direction over 30 minutes measured above the canopy, in 1993 at 7.65 m, in 1994 and 1996 at 6 m height
SDEV_WIND_DIR_MAG_ABV_CNPY	The standard deviation of the wind direction over 30 minutes measured above the canopy.
AIR_TEMP_ABV_CNPY	The air temperature measured above the canopy, in 1994 at 7.5 m and 1996 at 6 m height.
H2O_FLUX_ABV_CNPY	The water vapor flux measured above the canopy, in 1993 at 6 m, in 1994 and 1996 at 4.5 m height.
SOIL_HEAT_FLUX_HUMMOCK_10CM	The soil heat flux in a hummock measured at 10 cm depth.
SOIL_HEAT_FLUX_HOLLOW_10CM	The soil heat flux in a hollow measured at 10 cm depth.
SOIL_HEAT_FLUX_FEN	The soil heat flux for the whole fen surface, calculated as the product of the measured flux at the hollow and a factor (3.04 in 1994).
SOIL_TEMP_HUMMOCK_1CM	Soil temperature in a hummock at 1 cm depth.
SOIL_TEMP_HUMMOCK_5CM	Soil temperature in a hummock at 5 cm depth.
SOIL_TEMP_HUMMOCK_10CM	Soil temperature in a hummock at 10 cm depth.
SOIL_TEMP_HUMMOCK_25CM	Soil temperature in a hummock at 25 cm depth.
SOIL_TEMP_HUMMOCK_50CM	Soil temperature in a hummock at 50 cm depth.
SOIL_TEMP_HUMMOCK_75CM	Soil temperature in a hummock at 75 cm depth.
SOIL_TEMP_HUMMOCK_100CM	Soil temperature in a hummock at 1 m depth.
SOIL_TEMP_HUMMOCK_150CM	Soil temperature in a hummock at 1.5 m depth.
SOIL_TEMP_HUMMOCK_200CM	Soil temperature in a hummock at 2 m depth.
SOIL_TEMP_HOLLOW_1CM	Soil temperature in a hollow at 1 cm depth.
SOIL_TEMP_HOLLOW_5CM	Soil temperature in a hollow at 5 cm depth.
SOIL_TEMP_HOLLOW_10CM	Soil temperature in a hollow at 10 cm depth.
SOIL_TEMP_HOLLOW_25CM	Soil temperature in a hollow at 25 cm depth.
SOIL_TEMP_HOLLOW_50CM	Soil temperature in a hollow at 50 cm depth.
SOIL_TEMP_HOLLOW_75CM	Soil temperature in a hollow at 75 cm depth.
SOIL_TEMP_HOLLOW_100CM	Soil temperature in a hollow at 1 m depth.
SOIL_TEMP_HOLLOW_150CM	Soil temperature in a hollow at 1.5 m depth.
SOIL_TEMP_HOLLOW_200CM	Soil temperature in a hollow at 2 m depth.
RAINFALL	The amount of rainfall measured above the canopy in the 30 minute period following the time of observation, measured at 1 m height all years.
DOWN_SOLAR_RAD_ABV_CNPY	The downward (incoming) solar radiation measured above the canopy, measured at 10.47 m height in all years.
UP_SOLAR_RAD_ABV_CNPY	The reflected (outgoing) solar radiation measured above the canopy, measured at 10.23 m height in all years.
NET_SOLAR_RAD_ABV_CNPY	The net solar radiation measured above the canopy, measured at 10.35 m height in all years.
UP_TOTAL_RAD_ABV_CNPY	The total upward (outgoing) radiation measured above the canopy, in 1993 at 10.28 m, in 1994 at 10.23 m, and in 1996 at 10.28 m height.
AIR_TEMP_250CM	The air temperature measured at 2.5 meters above the ground.
AIR_TEMP_257CM	The air temperature measured at 2.57 meters above the ground.
AIR_TEMP_325CM	The air temperature measured at 3.25 meters above

	the ground.
AIR_TEMP_359CM	The air temperature measured at 3.59 meters above the ground.
AIR_TEMP_400CM	The air temperature measured at 4 meters above the ground.
AIR_TEMP_465CM	The air temperature measured at 4.65 meters above the ground.
AIR_TEMP_500CM	The air temperature measured at 5 meters above the ground.
AIR_TEMP_575CM	The air temperature measured at 5.75 meters above the ground.
AIR_TEMP_600CM	The air temperature measured at 6 meters above the ground.
AIR_TEMP_655CM	The air temperature measured at 6.55 meters above the ground.
AIR_TEMP_765CM	The air temperature measured at 7.65 meters above the ground.
WET_BULB_TEMP_250CM	The wet bulb temperature measured at 2.5 meters above the ground.
WET_BULB_TEMP_257CM	The wet bulb temperature measured at 2.57 meters above the ground.
WET_BULB_TEMP_325CM	The wet bulb temperature measured at 3.25 meters above the ground.
WET_BULB_TEMP_359CM	The wet bulb temperature measured at 3.59 meters above the ground.
WET_BULB_TEMP_400CM	The wet bulb temperature measured at 4 meters above the ground.
WET_BULB_TEMP_465CM	The wet bulb temperature measured at 4.65 meters above the ground.
WET_BULB_TEMP_500CM	The wet bulb temperature measured at 5 meters above the ground.
WET_BULB_TEMP_575CM	The wet bulb temperature measured at 5.75 meters above the ground.
WET_BULB_TEMP_600CM	The wet bulb temperature measured at 6 meters above the ground.
WET_BULB_TEMP_655CM	The wet bulb temperature measured at 6.55 meters above the ground.
WET_BULB_TEMP_765CM	The wet bulb temperature measured at 7.65 meters above the ground.
WET_BULB_TEMP_ABV_CNPY	The wet bulb temperature measured above the canopy, in 1994 at 7.5 m height.
VAPOR_PRESS_250CM	The vapor pressure measured at 2.5 meters above the ground.
VAPOR_PRESS_257CM	The vapor pressure measured at 2.57 meters above the ground.
VAPOR_PRESS_325CM	The vapor pressure measured at 3.25 meters above the ground.
VAPOR_PRESS_359CM	The vapor pressure measured at 3.59 meters above the ground.
VAPOR_PRESS_400CM	The vapor pressure measured at 4 meters above the ground.
VAPOR_PRESS_465CM	The vapor pressure measured at 4.65 meters above the ground.
VAPOR_PRESS_500CM	The vapor pressure measured at 5 meters above

	the ground.
VAPOR_PRESS_575CM	The vapor pressure measured at 5.75 meters above the ground.
VAPOR_PRESS_600CM	The vapor pressure measured at 6 meters above the ground.
VAPOR_PRESS_655CM	The vapor pressure measured at 6.55 meters above the ground.
VAPOR_PRESS_765CM	The vapor pressure measured at 7.65 meters above the ground.
VAPOR_PRESS_ABV_CNPY	The vapor pressure measured above the canopy, in 1994 at 7.5 m and in 1996 at 4.5 m height.
SURF_PRESS	The atmospheric pressure measured at the station
WATER_TABLE_HGT	Water table height above a reference surface.
DOWN_LONGWAVE_RAD_ABV_CNPY	The downward (incoming) longwave radiation measured above the canopy, in all years measured at 10.33 m height
UP_LONGWAVE_RAD_ABV_CNPY	The upward (outgoing) longwave radiation measured above the canopy, in all years measured at 10.33 m height
DOWN_TOTAL_RAD_ABV_CNPY	The total downward (incoming) radiation measured above the canopy, in all years measured at 10.41 m height
CORR_NET_RAD_ABV_CNPY	The corrected net radiation measured above the canopy, using equations developed by Hodges and Smith (1997).
ALBEDO	Surface solar albedo.
TOTAL_HEAT_STORAGE	Total of minor heat storage terms including soil heat flux and sensible and latent heat storage in the air.
SENSIBLE_AIR_HEAT_STORAGE	Sensible heat storage in air column between the surface and net pyrradiometer.
LATENT_AIR_HEAT_STORAGE	Latent heat storage in air column between the surface and net pyrradiometer.
MEAN_SPECIFIC_HUM_ABV_CNPY	The 30 minute mean specific humidity measured above the canopy, in 1994 and 1996 at 4.5 m height.
SDEV_SPECIFIC_HUM_ABV_CNPY	The 30 minute standard deviation of specific humidity measured above the canopy.
MEAN_W_WIND_SPEED_ABV_CNPY	The 30 minute mean of the vertical wind speed measured above the canopy, in 1994 and 1996 at 4.5 m height.
SDEV_W_WIND_SPEED_ABV_CNPY	The 30 minute standard deviation of the vertical wind speed measured above the canopy.
REL_HUM_ABV_CNPY	The relative humidity measured above the canopy, in 1996 at 4 m height.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
SENSIBLE_HEAT_FLUX_ABV_CNPY	[Watts][meter^-2]
LATENT_HEAT_FLUX_ABV_CNPY	[Watts][meter^-2]
NET_RAD_ABV_CNPY	[Watts][meter^-2]
CO2_FLUX_ABV_CNPY	[micromoles][meter^-2][second^-1]
CO2_CONC_ABV_CNPY	[parts per million]
CO2_STORAGE	[micromoles][meter^-2][second^-1]
CO2_FLUX_ABV_PLUS_STORAGE	[micromoles][meter^-2][second^-1]
DOWN_PPFD_ABV_CNPY	[micromoles][meter^-2][second^-1]
UP_PPFD_ABV_CNPY	[micromoles][meter^-2][second^-1]
WIND_SPEED_250CM	[meters][second^-1]
WIND_SPEED_325CM	[meters][second^-1]
WIND_SPEED_359CM	[meters][second^-1]
WIND_SPEED_400CM	[meters][second^-1]
WIND_SPEED_465CM	[meters][second^-1]
WIND_SPEED_500CM	[meters][second^-1]
WIND_SPEED_575CM	[meters][second^-1]
WIND_SPEED_655CM	[meters][second^-1]
WIND_SPEED_765CM	[meters][second^-1]
WIND_SPEED_ABV_CNPY	[meters][second^-1]
MEAN_WIND_DIR_MAG_ABV_CNPY	[degrees from magnetic north]
SDEV_WIND_DIR_MAG_ABV_CNPY	[degrees from magnetic north]
AIR_TEMP_ABV_CNPY	[degrees Celsius]
H2O_FLUX_ABV_CNPY	[millimoles][meter^-2][second^-1]
SOIL_HEAT_FLUX_HUMMOCK_10CM	[Watts][meter^-2]
SOIL_HEAT_FLUX_HOLLOW_10CM	[Watts][meter^-2]
SOIL_HEAT_FLUX_FEN	[Watts][meter^-2]
SOIL_TEMP_HUMMOCK_1CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_5CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_10CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_25CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_50CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_75CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_100CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_150CM	[degrees Celsius]
SOIL_TEMP_HUMMOCK_200CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_1CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_5CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_10CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_25CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_50CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_75CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_100CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_150CM	[degrees Celsius]
SOIL_TEMP_HOLLOW_200CM	[degrees Celsius]
RAINFALL	[millimeters]
DOWN_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]

UP_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]
NET_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]
UP_TOTAL_RAD_ABV_CNPY	[Watts][meter^-2]
AIR_TEMP_250CM	[degrees Celsius]
AIR_TEMP_257CM	[degrees Celsius]
AIR_TEMP_325CM	[degrees Celsius]
AIR_TEMP_359CM	[degrees Celsius]
AIR_TEMP_400CM	[degrees Celsius]
AIR_TEMP_465CM	[degrees Celsius]
AIR_TEMP_500CM	[degrees Celsius]
AIR_TEMP_575CM	[degrees Celsius]
AIR_TEMP_600CM	[degrees Celsius]
AIR_TEMP_655CM	[degrees Celsius]
AIR_TEMP_765CM	[degrees Celsius]
WET_BULB_TEMP_250CM	[degrees Celsius]
WET_BULB_TEMP_257CM	[degrees Celsius]
WET_BULB_TEMP_325CM	[degrees Celsius]
WET_BULB_TEMP_359CM	[degrees Celsius]
WET_BULB_TEMP_400CM	[degrees Celsius]
WET_BULB_TEMP_465CM	[degrees Celsius]
WET_BULB_TEMP_500CM	[degrees Celsius]
WET_BULB_TEMP_575CM	[degrees Celsius]
WET_BULB_TEMP_600CM	[degrees Celsius]
WET_BULB_TEMP_655CM	[degrees Celsius]
WET_BULB_TEMP_765CM	[degrees Celsius]
WET_BULB_TEMP_ABV_CNPY	[degrees Celsius]
VAPOR_PRESS_250CM	[kiloPascals]
VAPOR_PRESS_257CM	[kiloPascals]
VAPOR_PRESS_325CM	[kiloPascals]
VAPOR_PRESS_359CM	[kiloPascals]
VAPOR_PRESS_400CM	[kiloPascals]
VAPOR_PRESS_465CM	[kiloPascals]
VAPOR_PRESS_500CM	[kiloPascals]
VAPOR_PRESS_575CM	[kiloPascals]
VAPOR_PRESS_600CM	[kiloPascals]
VAPOR_PRESS_655CM	[kiloPascals]
VAPOR_PRESS_765CM	[kiloPascals]
VAPOR_PRESS_ABV_CNPY	[kiloPascals]
SURF_PRESS	[kiloPascals]
WATER_TABLE_HGT	[millimeters]
DOWN_LONGWAVE_RAD_ABV_CNPY	[Watts][meter^-2]
UP_LONGWAVE_RAD_ABV_CNPY	[Watts][meter^-2]
DOWN_TOTAL_RAD_ABV_CNPY	[Watts][meter^-2]
CORR_NET_RAD_ABV_CNPY	[Watts][meter^-2]
ALBEDO	[unitless]
TOTAL_HEAT_STORAGE	[Watts][meter^-2]
SENSIBLE_AIR_HEAT_STORAGE	[Watts][meter^-2]
LATENT_AIR_HEAT_STORAGE	[Watts][meter^-2]
MEAN_SPECIFIC_HUM_ABV_CNPY	[grams][kilogram^-1]
SDEV_SPECIFIC_HUM_ABV_CNPY	[grams][kilogram^-1]
MEAN_W_WIND_SPEED_ABV_CNPY	[meters][second^-1]
SDEV_W_WIND_SPEED_ABV_CNPY	[meters][second^-1]
REL_HUM_ABV_CNPY	[percent]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS.]
SUB_SITE	[Assigned by BORIS.]
DATE_OBS	[Supplied by Investigator.]
TIME_OBS	[Supplied by Investigator.]
SENSIBLE_HEAT_FLUX_ABV_CNPY	[sonic anemometer and thermocouple]
LATENT_HEAT_FLUX_ABV_CNPY	[sonic anemometer and krypton hygrometer]
NET_RAD_ABV_CNPY	[net pyrradiometer]
CO2_FLUX_ABV_CNPY	[IRGA and sonic anemometer]
CO2_CONC_ABV_CNPY	[IRGA]
CO2_STORAGE	[IRGA and sonic anemometer]
CO2_FLUX_ABV_PLUS_STORAGE	[IRGA and sonic anemometer]
DOWN_PPFD_ABV_CNPY	[quantum sensor]
UP_PPFD_ABV_CNPY	[quantum sensor]
WIND_SPEED_250CM	[anemometer]
WIND_SPEED_325CM	[anemometer]
WIND_SPEED_359CM	[anemometer]
WIND_SPEED_400CM	[anemometer]
WIND_SPEED_465CM	[anemometer]
WIND_SPEED_500CM	[anemometer]
WIND_SPEED_575CM	[anemometer]
WIND_SPEED_655CM	[anemometer]
WIND_SPEED_765CM	[anemometer]
WIND_SPEED_ABV_CNPY	[anemometer]
MEAN_WIND_DIR_MAG_ABV_CNPY	[wind vane]
SDEV_WIND_DIR_MAG_ABV_CNPY	[wind vane]
AIR_TEMP_ABV_CNPY	[thermocouple]
H2O_FLUX_ABV_CNPY	[sonic anemometer and krypton hygrometer]
SOIL_HEAT_FLUX_HUMMOCK_10CM	[heat flux plate]
SOIL_HEAT_FLUX_HOLLOW_10CM	[heat flux plate]
SOIL_HEAT_FLUX_FEN	[Supplied by Investigator.]
SOIL_TEMP_HUMMOCK_1CM	[thermocouple]
SOIL_TEMP_HUMMOCK_5CM	[thermocouple]
SOIL_TEMP_HUMMOCK_10CM	[thermocouple]
SOIL_TEMP_HUMMOCK_25CM	[thermocouple]
SOIL_TEMP_HUMMOCK_50CM	[thermocouple]
SOIL_TEMP_HUMMOCK_75CM	[thermocouple]
SOIL_TEMP_HUMMOCK_100CM	[thermocouple]
SOIL_TEMP_HUMMOCK_150CM	[thermocouple]
SOIL_TEMP_HUMMOCK_200CM	[thermocouple]
SOIL_TEMP_HOLLOW_1CM	[thermocouple]
SOIL_TEMP_HOLLOW_5CM	[thermocouple]
SOIL_TEMP_HOLLOW_10CM	[thermocouple]
SOIL_TEMP_HOLLOW_25CM	[thermocouple]
SOIL_TEMP_HOLLOW_50CM	[thermocouple]
SOIL_TEMP_HOLLOW_75CM	[thermocouple]
SOIL_TEMP_HOLLOW_100CM	[thermocouple]
SOIL_TEMP_HOLLOW_150CM	[thermocouple]
SOIL_TEMP_HOLLOW_200CM	[thermocouple]
RAINFALL	[tipping bucket gauge]
DOWN_SOLAR_RAD_ABV_CNPY	[pyranometer]

UP_SOLAR_RAD_ABV_CNPY	[pyranometer]
NET_SOLAR_RAD_ABV_CNPY	[Supplied by Investigator.]
UP_TOTAL_RAD_ABV_CNPY	[Supplied by Investigator.]
AIR_TEMP_250CM	[thermocouple]
AIR_TEMP_257CM	[thermocouple]
AIR_TEMP_325CM	[thermocouple]
AIR_TEMP_359CM	[thermocouple]
AIR_TEMP_400CM	[thermocouple]
AIR_TEMP_465CM	[thermocouple]
AIR_TEMP_500CM	[thermocouple]
AIR_TEMP_575CM	[thermocouple]
AIR_TEMP_600CM	[thermocouple]
AIR_TEMP_655CM	[thermocouple]
AIR_TEMP_765CM	[thermocouple]
WET_BULB_TEMP_250CM	[thermocouple]
WET_BULB_TEMP_257CM	[thermocouple]
WET_BULB_TEMP_325CM	[thermocouple]
WET_BULB_TEMP_359CM	[thermocouple]
WET_BULB_TEMP_400CM	[thermocouple]
WET_BULB_TEMP_465CM	[thermocouple]
WET_BULB_TEMP_500CM	[thermocouple]
WET_BULB_TEMP_575CM	[thermocouple]
WET_BULB_TEMP_600CM	[thermocouple]
WET_BULB_TEMP_655CM	[thermocouple]
WET_BULB_TEMP_765CM	[thermocouple]
WET_BULB_TEMP_ABV_CNPY	[thermocouple]
VAPOR_PRESS_250CM	[temperature/relative humidity sensor]
VAPOR_PRESS_257CM	[temperature/relative humidity sensor]
VAPOR_PRESS_325CM	[temperature/relative humidity sensor]
VAPOR_PRESS_359CM	[temperature/relative humidity sensor]
VAPOR_PRESS_400CM	[temperature/relative humidity sensor]
VAPOR_PRESS_465CM	[temperature/relative humidity sensor]
VAPOR_PRESS_500CM	[temperature/relative humidity sensor]
VAPOR_PRESS_575CM	[temperature/relative humidity sensor]
VAPOR_PRESS_600CM	[temperature/relative humidity sensor]
VAPOR_PRESS_655CM	[temperature/relative humidity sensor]
VAPOR_PRESS_765CM	[temperature/relative humidity sensor]
VAPOR_PRESS_ABV_CNPY	[temperature/relative humidity sensor]
SURF_PRESS	[pressure sensor]
WATER_TABLE_HGT	[water level recorder]
DOWN_LONGWAVE_RAD_ABV_CNPY	[pyrgeometer]
UP_LONGWAVE_RAD_ABV_CNPY	[pyrgeometer]
DOWN_TOTAL_RAD_ABV_CNPY	[Supplied by Investigator.]
CORR_NET_RAD_ABV_CNPY	[Supplied by Investigator.]
ALBEDO	[Supplied by Investigator.]
TOTAL_HEAT_STORAGE	[Supplied by Investigator.]
SENSIBLE_AIR_HEAT_STORAGE	[Supplied by Investigator.]
LATENT_AIR_HEAT_STORAGE	[Supplied by Investigator.]
MEAN_SPECIFIC_HUM_ABV_CNPY	[krypton hygrometer]
SDEV_SPECIFIC_HUM_ABV_CNPY	[krypton hygrometer]
MEAN_W_WIND_SPEED_ABV_CNPY	[sonic anemometer]
SDEV_W_WIND_SPEED_ABV_CNPY	[sonic anemometer]
REL_HUM_ABV_CNPY	[temperature/relative humidity sensor]
CRTFCN_CODE	[Assigned by BORIS.]
REVISION_DATE	[Assigned by BORIS.]

7.3.5 Data Range

The following table gives information about the parameter values found in the flux data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-FEN-FLXTR	NSA-FEN-FLXTR	None	None	None	None
SUB_SITE	9TF10-FLX01	9TF10-FLX01	None	None	None	None
DATE_OBS	15-AUG-93	06-NOV-96	None	None	None	None
TIME_OBS	0	2330	None	None	None	None
SENSIBLE_HEAT_FLUX_ ABV_CNPY	-69.58	431.78	-999	None	None	None
LATENT_HEAT_FLUX_ABV_ CNPY	-49.08	351.22	-999	None	None	None
NET_RAD_ABV_CNPY	-95.93	746.88	-999	None	None	None
CO2_FLUX_ABV_CNPY	-18.984	22.981	-999	None	None	Blank
CO2_CONC_ABV_CNPY	287.4	647	-999	None	None	Blank
CO2_STORAGE	-9.46	6.5	-999	None	None	Blank
CO2_FLUX_ABV_PLUS_ STORAGE	-20.341	21.233	-999	None	None	Blank
DOWN_PPFD_ABV_CNPY	0	2035	-999	None	None	None
UP_PPFD_ABV_CNPY	0	1085	-999	None	None	None
WIND_SPEED_250CM	.197	8.48	-999	None	None	Blank
WIND_SPEED_325CM	.198	9.38	-999	None	None	Blank
WIND_SPEED_359CM	.198	5.331	-999	None	None	Blank
WIND_SPEED_400CM	.198	10	-999	None	None	Blank
WIND_SPEED_465CM	.198	5.647	-999	None	None	Blank
WIND_SPEED_500CM	.198	10.35	-999	None	None	Blank
WIND_SPEED_575CM	.198	5.917	-999	None	None	Blank
WIND_SPEED_655CM	.197	6.052	-999	None	None	Blank
WIND_SPEED_765CM	.194	6.063	-999	None	None	Blank
WIND_SPEED_ABV_CNPY	.194	10.33	-999	None	None	Blank
MEAN_WIND_DIR_MAG_ ABV_CNPY	.031	360	-999	None	None	Blank
SDEV_WIND_DIR_MAG_ ABV_CNPY	0	194.6	-999	None	None	Blank
AIR_TEMP_ABV_CNPY	-26.63	30.46	-999	None	None	Blank
H2O_FLUX_ABV_CNPY	-1.4033	8.0233	-999	None	None	None
SOIL_HEAT_FLUX_ HUMMOCK_10CM	-94.12	169.65	-999	None	None	None
SOIL_HEAT_FLUX_ HOLLOW_10CM	-52.86	207.5	-999	None	None	None
SOIL_HEAT_FLUX_FEN	-137.4	315.2	-999	None	None	Blank
SOIL_TEMP_HUMMOCK_ 1CM	-18.14	33.19	-999	None	None	None
SOIL_TEMP_HUMMOCK_ 5CM	-12.43	29.44	-999	None	None	None
SOIL_TEMP_HUMMOCK_ 10CM	-8.18	24.94	-999	None	None	None
SOIL_TEMP_HUMMOCK_ 25CM	-3.379	22.29	-999	None	None	None
SOIL_TEMP_HUMMOCK_ 50CM	-.949	15.78	-999	None	None	None

SOIL_TEMP_HUMMOCK_75CM	.05	12.87	-999	None	None	None
SOIL_TEMP_HUMMOCK_100CM	.42	11.1	-999	None	None	None
SOIL_TEMP_HUMMOCK_150CM	1.28	8.94	-999	None	None	None
SOIL_TEMP_HUMMOCK_200CM	2.04	7.49	-999	None	None	None
SOIL_TEMP_HOLLOW_1CM	-8.76	34.52	-999	None	None	None
SOIL_TEMP_HOLLOW_5CM	-5.11	31.25	-999	None	None	None
SOIL_TEMP_HOLLOW_10CM	-2.19	24.19	-999	None	None	None
SOIL_TEMP_HOLLOW_25CM	-1.032	17.77	-999	None	None	None
SOIL_TEMP_HOLLOW_50CM	-.172	13.85	-999	None	None	None
SOIL_TEMP_HOLLOW_75CM	.31	11.76	-999	None	None	None
SOIL_TEMP_HOLLOW_100CM	.77	9.94	-999	None	None	None
SOIL_TEMP_HOLLOW_150CM	1.57	7.48	-999	None	None	None
SOIL_TEMP_HOLLOW_200CM	2.32	6.23	-999	None	None	None
RAINFALL	0	11.2	-999	None	None	Blank
DOWN_SOLAR_RAD_ABV_CNPY	0	975	-999	None	None	None
UP_SOLAR_RAD_ABV_CNPY	0	536.5	-999	None	None	None
NET_SOLAR_RAD_ABV_CNPY	0	854.9	-999	None	None	None
UP_TOTAL_RAD_ABV_CNPY	202.6	775.8	-999	None	None	None
AIR_TEMP_250CM	-28.22	30.46	-999	None	None	Blank
AIR_TEMP_257CM	-2.283	26.74	-999	None	None	Blank
AIR_TEMP_325CM	-27.57	29.66	-999	None	None	Blank
AIR_TEMP_359CM	-2.227	26.66	-999	None	None	Blank
AIR_TEMP_400CM	-27.44	29.31	-999	None	None	Blank
AIR_TEMP_465CM	-2.211	26.56	-999	None	None	Blank
AIR_TEMP_500CM	-26.81	29.83	-999	None	None	Blank
AIR_TEMP_575CM	-2.238	26.42	-999	None	None	Blank
AIR_TEMP_600CM	-27.2	29.84	-999	None	None	Blank
AIR_TEMP_655CM	-2.234	26.46	-999	None	None	Blank
AIR_TEMP_765CM	-2.207	26.34	-999	None	None	Blank
WET_BULB_TEMP_250CM	-5.504	19.35	-999	None	None	Blank
WET_BULB_TEMP_257CM	-2.373	19.24	-999	None	None	Blank
WET_BULB_TEMP_325CM	-5.506	19.42	-999	None	None	Blank
WET_BULB_TEMP_359CM	-2.296	19.12	-999	None	None	Blank
WET_BULB_TEMP_400CM	-5.556	19.04	-999	None	None	Blank
WET_BULB_TEMP_465CM	-2.215	19.1	-999	None	None	Blank
WET_BULB_TEMP_500CM	-5.512	19.03	-999	None	None	Blank
WET_BULB_TEMP_575CM	-2.165	18.88	-999	None	None	Blank
WET_BULB_TEMP_600CM	-5.514	19.01	-999	None	None	Blank
WET_BULB_TEMP_655CM	-2.268	19.13	-999	None	None	Blank

WET_BULB_TEMP_765CM	-2.165	18.88	-999	None	None	Blank
WET_BULB_TEMP_ABV_CNPY	-5.437	18.84	-999	None	None	Blank
VAPOR_PRESS_250CM	.2806	2.0161	-999	None	None	Blank
VAPOR_PRESS_257CM	.5071	2.0547	-999	None	None	Blank
VAPOR_PRESS_325CM	.3295	1.9958	-999	None	None	Blank
VAPOR_PRESS_359CM	.51	2.0302	-999	None	None	Blank
VAPOR_PRESS_400CM	.2968	1.9958	-999	None	None	Blank
VAPOR_PRESS_465CM	.5173	2.0225	-999	None	None	Blank
VAPOR_PRESS_500CM	.2865	1.9925	-999	None	None	Blank
VAPOR_PRESS_575CM	.5236	2.0413	-999	None	None	Blank
VAPOR_PRESS_600CM	.3273	1.9918	-999	None	None	Blank
VAPOR_PRESS_655CM	.5148	2.0275	-999	None	None	Blank
VAPOR_PRESS_765CM	.5222	2.0096	-999	None	None	Blank
VAPOR_PRESS_ABV_CNPY	.0809	2.2266	-999	None	None	Blank
SURF_PRESS	96	99.9	-999	None	None	Blank
WATER_TABLE_HGT	-110.7	87.33	-999	None	None	Blank
DOWN_LONGWAVE_RAD_ABV_CNPY	118.78	433.6	-999	None	None	None
UP_LONGWAVE_RAD_ABV_CNPY	202.6	513.8	-999	None	None	None
DOWN_TOTAL_RAD_ABV_CNPY	139.39	1295.8	-999	None	None	None
CORR_NET_RAD_ABV_CNPY	-92.41	717.96	-999	None	None	Blank
ALBEDO	0	.9177	-999	None	None	None
TOTAL_HEAT_STORAGE	-137.8	317.7	-999	None	None	None
SENSIBLE_AIR_HEAT_STORAGE	-32.2	38	-999	None	None	None
LATENT_AIR_HEAT_STORAGE	-39.5	36	-999	None	None	None
MEAN_SPECIFIC_HUM_ABV_CNPY	1.57	26.23	-999	None	None	Blank
SDEV_SPECIFIC_HUM_ABV_CNPY	0	56.297	-999	None	None	Blank
MEAN_W_WIND_SPEED_ABV_CNPY	-1.998	3.28	-999	None	None	Blank
SDEV_W_WIND_SPEED_ABV_CNPY	0	3.815	-999	None	None	Blank
REL_HUM_ABV_CNPY	15.2	107	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	07-DEC-98	08-DEC-98	None	None	None	None

Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.
Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to

```
                        indicate that an attempt was made to determine the
                        parameter value, but the analysis personnel determined
                        that the parameter value was below the detection
                        limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
                        determine the parameter value.  This usually
                        indicates that BORIS combined several similar but
                        not identical data sets into the same data base table
                        but this particular science team did not
                        measure that parameter.
Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
--------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following are wrapped versions of data record from a sample flux data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SENSIBLE_HEAT_FLUX_ABV_CNPY,
LATENT_HEAT_FLUX_ABV_CNPY,NET_RAD_ABV_CNPY,CO2_FLUX_ABV_CNPY,CO2_CONC_ABV_CNPY,
CO2_STORAGE,CO2_FLUX_ABV_PLUS_STORAGE,DOWN_PPFD_ABV_CNPY,UP_PPFD_ABV_CNPY,
WIND_SPEED_250CM,WIND_SPEED_325CM,WIND_SPEED_359CM,WIND_SPEED_400CM,
WIND_SPEED_465CM,WIND_SPEED_500CM,WIND_SPEED_575CM,WIND_SPEED_655CM,
WIND_SPEED_765CM,WIND_SPEED_ABV_CNPY,MEAN_WIND_DIR_MAG_ABV_CNPY,
SDEV_WIND_DIR_MAG_ABV_CNPY,AIR_TEMP_ABV_CNPY,H2O_FLUX_ABV_CNPY,
SOIL_HEAT_FLUX_HUMMOCK_10CM,SOIL_HEAT_FLUX_HOLLOW_10CM,SOIL_HEAT_FLUX_FEN,
SOIL_TEMP_HUMMOCK_1CM,SOIL_TEMP_HUMMOCK_5CM,SOIL_TEMP_HUMMOCK_10CM,
SOIL_TEMP_HUMMOCK_25CM,SOIL_TEMP_HUMMOCK_50CM,SOIL_TEMP_HUMMOCK_75CM,
SOIL_TEMP_HUMMOCK_100CM,SOIL_TEMP_HUMMOCK_150CM,SOIL_TEMP_HUMMOCK_200CM,
SOIL_TEMP_HOLLOW_1CM,SOIL_TEMP_HOLLOW_5CM,SOIL_TEMP_HOLLOW_10CM,
SOIL_TEMP_HOLLOW_25CM,SOIL_TEMP_HOLLOW_50CM,SOIL_TEMP_HOLLOW_75CM,
SOIL_TEMP_HOLLOW_100CM,SOIL_TEMP_HOLLOW_150CM,SOIL_TEMP_HOLLOW_200CM,RAINFALL,
DOWN_SOLAR_RAD_ABV_CNPY,UP_SOLAR_RAD_ABV_CNPY,NET_SOLAR_RAD_ABV_CNPY,
UP_TOTAL_RAD_ABV_CNPY,AIR_TEMP_250CM,AIR_TEMP_257CM,AIR_TEMP_325CM,
AIR_TEMP_359CM,AIR_TEMP_400CM,AIR_TEMP_465CM,AIR_TEMP_500CM,AIR_TEMP_575CM,
AIR_TEMP_600CM,AIR_TEMP_655CM,AIR_TEMP_765CM,WET_BULB_TEMP_250CM,
WET_BULB_TEMP_257CM,WET_BULB_TEMP_325CM,WET_BULB_TEMP_359CM,WET_BULB_TEMP_400CM,
WET_BULB_TEMP_465CM,WET_BULB_TEMP_500CM,WET_BULB_TEMP_575CM,WET_BULB_TEMP_600CM,
WET_BULB_TEMP_655CM,WET_BULB_TEMP_765CM,WET_BULB_TEMP_ABV_CNPY,
VAPOR_PRESS_250CM,VAPOR_PRESS_257CM,VAPOR_PRESS_325CM,VAPOR_PRESS_359CM,
VAPOR_PRESS_400CM,VAPOR_PRESS_465CM,VAPOR_PRESS_500CM,VAPOR_PRESS_575CM,
VAPOR_PRESS_600CM,VAPOR_PRESS_655CM,VAPOR_PRESS_765CM,VAPOR_PRESS_ABV_CNPY,
SURF_PRESS,WATER_TABLE_HGT,DOWN_LONGWAVE_RAD_ABV_CNPY,UP_LONGWAVE_RAD_ABV_CNPY,
DOWN_TOTAL_RAD_ABV_CNPY,CORR_NET_RAD_ABV_CNPY,ALBEDO,TOTAL_HEAT_STORAGE,
SENSIBLE_AIR_HEAT_STORAGE,LATENT_AIR_HEAT_STORAGE,MEAN_SPECIFIC_HUM_ABV_CNPY,
SDEV_SPECIFIC_HUM_ABV_CNPY,MEAN_W_WIND_SPEED_ABV_CNPY,SDEV_W_WIND_SPEED_ABV_CNPY,
REL_HUM_ABV_CNPY,CRTFCN_CODE,REVISION_DATE
'NSA-FEN-FLXTR','9TF10-FLX01',01-JUN-96,0,-18.87,-999.0,26.36,-999.0,-999.0,
-999.0,-999.0,0.0,0.0,3.129,,,-999.0,,,,,,3.576,65.29,19.19,3.38,-999.0,.5,
-.2,,4.4,4.83,5.43,5.84,.28,.4,.81,1.63,2.42,5.57,5.72,5.54,2.5,.29,.72,1.16,
2.04,2.74,.2,36.1,3.05,33.05,338.15,3.64,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
.7545,98.6,,328.41,335.1,364.51,28.43,.085,-.5,-.2,-.1,-999.0,-999.0,-.018,
.585,98.2,'CPI',08-DEC-98
```

```
'NSA-FEN-FLXTR','9TF10-FLX01',01-JUN-96,30,3.7,-999.0,19.64,-999.0,-999.0,
-999.0,-999.0,80.6,.337,3.128,,,-999.0,,,,,,3.567,72.3,18.73,7.7,-999.0,.27,
1.45,,8.05,8.49,9.28,9.42,.16,.4,.82,1.64,2.43,8.7,9.08,8.89,3.27,.29,.72,
1.16,2.04,2.74,0.0,33.29,2.99,30.3,356.39,7.95,,,,,,,,,,,,,,,,,,,,,,,,,,
,,,,,,.9495,98.2,,342.74,353.4,376.03,22.0,.09,2.3,.9,0.0,-999.0,-999.0,
-.006,.54,91.0,'CPI',08-DEC-98
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BORIS was data collected at a given site on a given date.

8.2 Data Format

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

Net Solar Radiation (W/m^2)

Net solar radiation (K*) is the difference between incoming solar radiation (Kd) and reflected solar radiation (Ku):

$$K^* = Kd - Ku \qquad (9.1)$$

Incoming Longwave Radiation (W/m^2)

Incoming longwave radiation (Ld) is calculated as a residual from the net radiation balance, where net radiation (Q*) is the sum of net solar radiation (K*, see e.g. 9.1) and net longwave radiation (L*). L* is the difference between incoming longwave radiation (Ld) and outgoing longwave radiation (Lu).

$$Q^* = Kd - Ku + Ld - Lu \qquad (9.2)$$

Total Incoming Radiation (W/m^2)

Total incoming radiation (Qd) is the sum of all incoming radiation:

$$Qd = Kd + Ld \qquad (9.3)$$

Total Outgoing Radiation (W/m^2)

Total outgoing radiation (Qu) is the sum of all outgoing radiation:

$$Qu = Ku + Lu \qquad (9.4)$$

Net Radiation corrected (W/m^2)

Measured net radiation (Q*) was corrected using a set of site-specific day- and night-time equations developed by Hodges and Smith (1997). These equations (shown below) were used for all years of data, excluding data collected in 1993 at both fen and YJP. The use of the day or night equation is based on measured incoming solar radiation. When Kd > 5.00 W/m^2, daytime equations are used. The relevant equations are:

Time of day Correction equation

DAY Q*corr = 0.957(Q*) + 3.2 (9.5)
NIGHT Q*corr = 1.079(Q*) + 11.1 (9.6)

Surface Albedo (dimensionless)

Surface albedo (a) is the ratio of the amount of radiation reflected by a body to the amount incident upon it:

a = Ku/Kd (9.7)

Total CO_2 Flux ($\mu mol/m^2/s$)

The total CO_2 flux (Fe_{CO2}) is the sum of the eddy flux (Fe_{CO2}) and the storage flux (Fs_{CO2}):

$F_{CO2} = Fe_{CO2} + Fs_{CO2}$ (9.8)

Heat Storage (W/m^2)

Total heat storage (G_total) is based on the sum of heat storage from several environmental compartments:

G_total = G + Ga + Ge + Gveg (9.9)

where: G = soil heat flux
Ga = sensible heat storage in the air
Ge = latent heat storage in the air
Gveg = heat storage in the vegetation

Only G is measured, and the remaining variables are calculated using the formulae given by Thom (1975):

Ga(T) = 0.33 zr dTa(t) (9.10)
Ge(T) = 0.5 zr de(t) (9.11)
Gveg(T) = 0.8 Mv dTb(t) (9.12)

where zr is the reference height (in this case the height of the net pyrradiometer)(m); dTa, de, and dTb are the rates of change in air temperature (°C/s), vapor pressure (kPa/s), and biomass temperature (°C/s), respectively, for time step t; and Mv is the standing green mass of vegetation over unit area (kg/m^2). Theoretically, Ga and Ge are integrated over the height interval between the surface and zr. In this study, the calculations were performed for discrete layers represented by the profile psychrometer heights and summed to get the totals. The calculation of all minor heat storage terms in the energy balance were calculated with the Fortran program called STORAG. An explanation of this program is given in Section 9.1.1, and a description of the command files used to process the data is given in Section 9.2.1.

Ground heat flux at the fen in 1994 only (Gfen) was computed by adjusting the heat flux plate readings from the hollow (Ghol) with a correction factor determined from calorimetric methods. In the following explanation, Gpla is equal to Ghol. Hence,

$$G = G(z)CF \qquad (9.13)$$

where $CF = Gcal/Gpla \qquad (9.14)$

in which CF is a correction factor (3.04) determined from calorimetric calculations of heat storage in the soil profile (Gcal) and the time integrated flux measured by the heat flux plates (Gpla). Gpla is calculated by summing the 30-minute average heat flux plate readings multiplied by 1800 seconds over a specified time interval (usually 10-14 days). Gcal is the total heat storage in the soil profile calculated from individual soil layers represented by the measured temperature profile(s), plus the heat flux out the bottom of the soil profile (GB).

Heat storage in the individual layers, S(i) is computed as:

$$S(i) = CdT(t)z \qquad (9.15)$$

where symbols are defined as above. C varies between 3.48 x 10^6 J/m^3/°C for saturated peat soil and 0.58 x 10⁶ J/m^3/°C for dry peat soil. The flux out the base of the soil profile is calculated as:

$$GB = -Ks\ dT/dz \qquad (9.16)$$

where -Ks is the thermal conductivity of saturated peat soil (0.5 W/m/°C) and dT/dz is the temperature gradient at the base of the soil profile.

In 1993, 1995, and 1996, no correction factor was applied to the fen's soil heat flux data (see Section 10.2.2). In these years, the soil heat flux from the hollow (Ghol) was used in the calculations of G_total.

Specific Humidity (g/kg)

Specific humidity (SH) and the standard deviation of specific humidity (sSH) were calculated using measured air temperature (T_air), vapor density (q), and the standard deviation of ln q (sln q).

Air density (rho) is found as a function of T_air, where:

```
if    T_air>30   then rho = 1.149 - 0.0036 (T_air - 30.01)   (9.17)
if 25>T_air>30   then rho = 1.168 - 0.0038 (T_air - 25.01)   (9.18)
if  20>T_air>25  then rho = 1.188 - 0.0040 (T_air - 20.01)   (9.19)
if  15>T_air>20  then rho = 1.209 - 0.0042 (T_air - 15.01)   (9.20)
if  10>T_air>15  then rho = 1.230 - 0.0042 (T_air - 10.01)   (9.21)
if   5>T_air>10  then rho = 1.252 - 0.0044 (T_air -  5.01)   (9.22)
if   0>T_air>5   then rho = 1.275 - 0.0046 (T_air -  0.01)   (9.23)
if  -5>T_air>0   then rho = 1.229 - 0.0048 (T_air +  4.99)   (9.24)
if -10>T_air>-5  then rho = 1.324 - 0.0050 (T_air +  9.99)   (9.25)
if -15>T_air>-10 then rho = 1.350 - 0.0050 (T_air + 14.99)   (9.26)
if -20>T_air>-15 then rho = 1.376 - 0.0054 (T_air + 19.99)   (9.27)
```

The specific humidity is found from the vapor density (g/m^3), measured by the krypton hygrometer at each site, and

$$q = (\ln s - \ln v)/kx \qquad (9.28)$$

where s = the signal voltage from the hygrometer (mv), v is the intercept of the hygrometer's calibration (4054 mv for the fen and 4528 mv for the YJP), k is absorption coefficient for water vapor (-0.141 m^3/g/cm for the fen and -0.133 m^3/g/cm for the YJP), and x is the path length of the hygrometer (1.542 cm for the fen and 1.400 cm for the YJP). Then,

$$SH = q/rho \qquad (9.29)$$ and
$$sSH = (e^{|s \ln q|})/rho \qquad (9.30)$$

where s indicates the standard deviation.

Convective Heat Fluxes (H and LE)

The sensible heat flux was found from equation 3.2 which states that

$$H = rho\ Cp\ \langle w'T' \rangle \qquad (9.31)$$

where the variables have their usual meanings. Webb (1982) showed that the air density and specific heat of air are functions of both the air's temperature and vapor pressure, and that air temperature had the largest control. Thus, in our calculations, the rho Cp term was corrected for changing temperature and air pressure as follows:

$$rho\ Cp = Cp(d)\ (P\ M/R\ T) \qquad (9.32)$$

where Cp(d) is the specific heat of dry air, P is the atmospheric pressure, M is the molecular weight of dry air, R is the universal gas constant, and T is the air temperature. In the 1994 experiments, P was obtained from Thompson airport and read into the data logger once a day, usually about 1500 UTC, when the site was first visited. In 1996, analog pressure sensors at the YJP and fen were recorded P every half-hour. The air temperature that was used was the average value from the previous half-hour, which was updated on a continuous basis automatically by the data logger. The precision of this correction was improved in 1996 because we incorporated air pressure sensors into the measurement packages at each site, and this allowed the use of the previous half-hour's air pressure as well as temperature in equation 9.41.

The value of L, the latent heat of vaporization, in the eddy covariance measurement of latent heat flux (equation 3.1) was found as a function of air temperature from the equation

$$L = 2501 + (-2.363)\ T + (-0.00023)\ T^2 \qquad (9.33)$$

where T is the air temperature averaged over the previous half-hour. Equation 9.42 was part of the online calculations.

The krypton lamp in the hygrometer has two emission lines, a major line at 123.58 nm, and a minor line at 116.49 nm. Both lines are absorbed by both water vapor and oxygen. It is necessary to account for the effect of absorption by oxygen on the value of vapor density in order to correct the latent heat flux. The oxygen correction is a function of atmospheric pressure and temperature, and Tanner, et al. (1993) provide the appropriate equations to find the oxygen correction. At standard atmospheric pressure (101.3 kP) and temperature (305 K), the pressure correction is small in comparison to that caused by temperature, and it is usual to correct for oxygen absorption based only on temperature. This procedure was followed in this experiment.

Webb et al. (1980) described the influence of sensible heat and vapor fluxes that cause changes in the density of atmospheric constituents, and the necessary corrections to the flux associated with these fluctuations. These corrections are usually termed the Webb, Pearman, and Leuning (WPL) corrections, and they were applied to the latent heat flux in this experiment (Joiner, 1994). The WPL correction due to the sensible heat flux is approximately five times larger than that due to the vapor flux itself (Tanner et al., 1993).

Carbon Dioxide Flux

Because we used a closed-path IRGA and the air sample was delivered to the instrument through a sample tube, there is a time delay, or lag, in the concentration of CO_2, measured in the IRGA, and the measured vertical wind in the free atmosphere around the sonic. If the CO_2 concentration data were not corrected for lag, we would not calculate the correct covariance, and the flux of CO_2 would be incorrect. We found the lag for our CO_2 systems at fen and YJP empirically. While continuously monitoring the output of CO_2 and vertical wind, we introduced a bubble of nitrogen in the vicinity of the sample tube intake. The arrival of the nitrogen in the sample cell of the IRGA caused a discernable spike in the CO_2 time series. We identified formally the time of occurrence of the spike by lag correlation analysis of CO_2 concentration and vertical wind. The lag was where the correlation coefficient between CO_2 and vertical wind was a maximum. Site-specific lag times were programmed into the data loggers at each site, and these lags allowed us to compute a covariance using the correct values of CO_2 and vertical wind.

The concentration of CO_2 measured by an IRGA is dependent on pressure. Changing pressure changes the calibration of the instrument (span/voltage difference) by changing the span. The span is the difference in concentration between the high and low span gases; in our case approximately 30 to 40 ppmv. The effect of changing pressure on the IRGA's calibration was corrected online.

Changes in the air's temperature and water vapor density, which in turn are related to the sensible and latent heat fluxes, affect the concentration of CO_2 and hence the flux of CO_2 (Webb et al., 1980). In postprocessing, the CO_2 flux was corrected for changing density and vapor flux (Joiner, 1994). The correction includes a correction for the cross-sensitivity of the IRGA to water vapor and carbon dioxide (Leuning and Moncrieff, 1990; Leuning and King, 1992).

9.1.1 Derivation Techniques and Algorithms

STORAG is the general name for a Fortran program that calculates the minor heat storage terms in the energy balance. There are several operational versions of the program that differ depending upon the available data (see Section 9.2.1). Also, ENBAL, a Fortran program to solve for the terms of the radiation balance, was used in the analysis. Both STORAG and ENBAL work on the principle of GET commands that read input data into memory from various files, and when sufficient variables are read to solve the control equations, the calculations get done and are stored in output tables that can be delivered to spreadsheets or plotting packages for further processing and plotting. An example of the operation of STORAG is given in Section 9.2.1 that illustrates not only the specific features of STORAG but also the general nature of both programs.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Two versions of STORAG were used in the calculations of heat storage depending on what data were available: STORY94.exe and STORY96.exe. STORY94.exe, used on 1993, 1994, and 1995 data, calculated heat storage variables from wet-bulb and dry-bulb temperatures, net radiation, soil heat flux, and soil temperatures. STORY96.exe was used on the 1996 data where relative humidity (RH) was an input measured variable, which replaced its calculation using wet-bulb temperatures.

A command file is used to run the STORAG program. It comprises a list of GET statements that select variables from a specified column in a specified file. The last two numbers in the GET statement are the slope and intercept of the equation to be used with those data. This is useful if the input data are in the wrong units, because a linear calibration can then be applied. Other variables are set using SET statements. Variables used in the STORY94 program are:

```
Q*       Net radiation
QGZ      Soil heat flux
TS1-3    Soil temperatures from depths of 1, 5, and 10 cm, respectively
TB       Biomass temperature (see Section 9.2.2)
TD1-6    Dry-bulb temperatures
Tw1-6    Wet-bulb temperatures (in STORY96, RH is used instead)
XW       Soil moisture content
HCS      Heat capacity of soil
TOL      Thickness of the organic layer
DS       Depth of temperature measurements
```

```
ZR       Height of the net radiation measurement
ZCQ      Height of canopy, height of net pyrradiometer
MV       Green mass of vegetation
CON      Constant used in equations determining Ga, Ge, and Gveg
```

An example of the command file used to run STORAG is listed in Table 14 for one day. All commands must be in capital letters, Q* and QGZ data must
be 30-minute averages, and the remaining temperatures are 15-minute averages.

Table 14. Example command file for STORAG, a program to find the minor heat storage terms in the surface energy balance.

```
SETPAUSE OFF
CLEAR
TITLE  YJP NORTH FOREST SITE  ENERGY STORAGE  MAY-24-1994 (144)
SETTIME 0.25 0.25 95
GET(Q*)   Y94307E.144 (24X,F8.0)   1.0 0.0
GET(QGZ)  Y94307E.144 (112X,F8.0)  1.0 0.0
GET(TS1)  Y94157E.144 (200X,F8.0)  1.0 0.0
GET(TS2)  Y94157E.144 (208X,F8.0)  1.0 0.0
GET(TS3)  Y94157E.144 (216X,F8.0)  1.0 0.0
GET(TB)   Y94157E.144 (40X,F8.0)   1.0 0.0
GET(TD1)  Y94157E.144 (48X,F8.0)   1.0 0.0
GET(TD2)  Y94157E.144 (56X,F8.0)   1.0 0.0
GET(TD3)  Y94157E.144 (64X,F8.0)   1.0 0.0
GET(TD4)  Y94157E.144 (72X,F8.0)   1.0 0.0
GET(TD5)  Y94157E.144 (80X,F8.0)   1.0 0.0
GET(TD6)  Y94157E.144 (88X,F8.0)   1.0 0.0
GET(TW1)  Y94157E.144 (96X,F8.0)   1.0 0.0
GET(TW2)  Y94157E.144 (104X,F8.0)  1.0 0.0
GET(TW3)  Y94157E.144 (104X,F8.0)  1.0 0.0
GET(TW4)  Y94157E.144 (120X,F8.0)  1.0 0.0
GET(TW5)  Y94157E.144 (128X,F8.0)  1.0 0.0
GET(TW6)  Y94157E.144 (136X,F8.0)  1.0 0.0
SET(XW)   0.08 0.08
SET(HCS)  0.1455 0.2067
SET(TOL)  0.03
SET(DS)   0.01 0.05 0.1
SET(ZR)   1.5 5.07 6.0 7.05 7.6 10.2
SET(ZCQ)  3.0 11.60
SET(MV)   0.888
SET(CON)  0.8
SHOW
WRITE     Y94STORN.144
WRITESTO  Y94QSN.144
```

9.2.2 Processing Changes

Where one level of air temperature was missing from a file used in STORAG, the GET statement was changed to read the value from the nearest level. For example, if the third level of temperature is missing, the value from the fourth level could be used instead.

Mass of vegetation (MV) is zero in the fen calculations. For heat storage calculations at YJP in the west site, MV = 2.22. Because there were only small trees in the north site, MV was equal to 0.888 for this site. Biomass temperature (TB) is zero in the fen calculations, whereas it is based on the stem temperatures at YJP. In the north site, TB = Tbsn. In the west site, the following weighted average, based on the percentage occurrence of small, medium, and large trees, was used to determine TB:

$$TB = 0.4\ Tbsw + 0.486\ Tbmw + 0.114\ Tblw \qquad (9.34)$$

The STORAG program does not accept zero in the command file; therefore, the TB multiplier, the thickness of the organic layer (TOL), the height of the canopy, and MV were set to 0.000001 in the fen calculations, creating insignificant values in the calculated heat storage.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

The following rules were followed in preparing the data files:

- Any small negative values of Kd and Ku (<1 W/m^2) were changed to zero, and Ld, Qd, Qu, and the albedo were recalculated accordingly; negative values occur as a result of zero depression on the instruments.
- All negative values of incoming and reflected PPFD (PPFDd and PPFDu) were changed to zero; as is the case with pyranometers, small negative values result from zero depression.
- When $FsCO_2$ was missing and Kd>0, then $F_{CO2} = Fe_{CO2}$.
- When $FsCO_2$ was missing and Kd=0, then $F_{CO2} = CO_2night$.
- Latent heat flux (LE) was flagged (i.e., changed to -6999) when LE<-50 W/m^2.
- Sensible heat flux (H) was flagged when H<-70 W/m^2.
- All negative wind speeds were flagged.
- Where LE was flagged and vertical wind speed (w) was >2 or <-2 m/s, w was flagged.
- Where between one and three half-hourly average values of a variable were missing, a linear interpolation was done, assuming that the meteorological conditions were steady and a clear temporal trend was present before and after the data gap.

9.3.2 Calculated Variables

Formulae for the following list of calculated variables can be found in Section 9.1: K*, Ld, Qd, Qu, Q*, Q*corr, a, F_{CO2}, CO_2night, G_total, Ga, Ge, Gveg, G10, SH, and sSH.

9.4 Graphs and Plots

Day 260 in 1996 was chosen because it was a clear day and it shows many interesting contrasting features of the radiation, energy, and CO_2 balances of the two sites (Figure 4). The time shown in the figure is UTC. The most notable differences in the radiation balances between the two sites (Figure 4A and 4B) occur in the net radiation (Q*) and reflected solar radiation (Ku) components: the latter is larger and the former is smaller at the fen as a result of i) the larger albedo at the fen and ii) the higher surface temperatures on the jack pine; which increase the outgoing longwave radiation (Lu) from the drier surface; the greatest contrast in Lu occurs early in the day. The incoming solar radiation (Kd) and incoming longwave radiation (Ld) do not indicate substantial differences between the sites.

The fen had started to senesce by day 260; as a result, the majority of the available energy goes into sensible heat flux (average Bowen ratio 2.0) (Figure 4C). The YJP was still actively transpiring (average Bowen ratio 1.0), except for a short period in the middle of the day when the sensible heat flux exceeds the latent heat flux (Figure 4D). The value of the total heat storage (G_total) includes the soil heat storage and biomass storage from the north site.

The impact of senescence is very noticeable in the different net CO_2 flux patterns. The fen is either effluxing or in a state of zero net exchange for the majority of the day (Figure 4E), but there is some very weak uptake in the late morning. The jack pine shows vigorous uptake for the whole daylight period and consistent efflux in the nighttime period at the start of the day (Figure 4F). The pattern of efflux breaks down late in the day under the very calm wind speed conditions (Figure 4H).

The pattern of wind at the fen is characterized by very low wind speed or complete calm during the night and maximum values of 5 m/s during the daylight period (Figure 4G). The increase of wind speed in the morning and the decrease in the evening are very sharp. The pattern at the YJP is quite different early in the day, when the wind speed increases gradually to a maximum of only 3 m/s by the evening. The precipitous drop in wind speed at 0000 UTC is the same pattern as at the fen. The direction of the wind was steadier at the fen, where it blew from the southeast from 1200 UTC onwards. At the YJP, the direction was more easterly for the majority of the day. It is clear that the fen has its own particular wind climate, and on very calm nights such as the start of day 260, it is much calmer than the more open YJP site (compare Figures 4G and 4H).

The slightly higher and more gradually declining air temperatures at the YJP in the early part of the day (Figure 4H) are consistent with the presence of the higher wind speeds, which would have mixed the lower atmosphere more effectively. The increased mixing would hinder the development of a surface temperature inversion and raise the air temperature. It is important to note that the eddy covariance measurement of CO_2 was very successful at this time of the day, when a constant efflux of 1 µmole/m^2/s was measured (Figure 4F). The same is not true for the fen, where the CO_2 series is quite jagged (Figure 4E) as a result of measured negative fluxes that have been set to zero as part of the data management. Clearly, the measurement of the flux was breaking down at the fen under the totally calm wind speed conditions (Figure 4G).

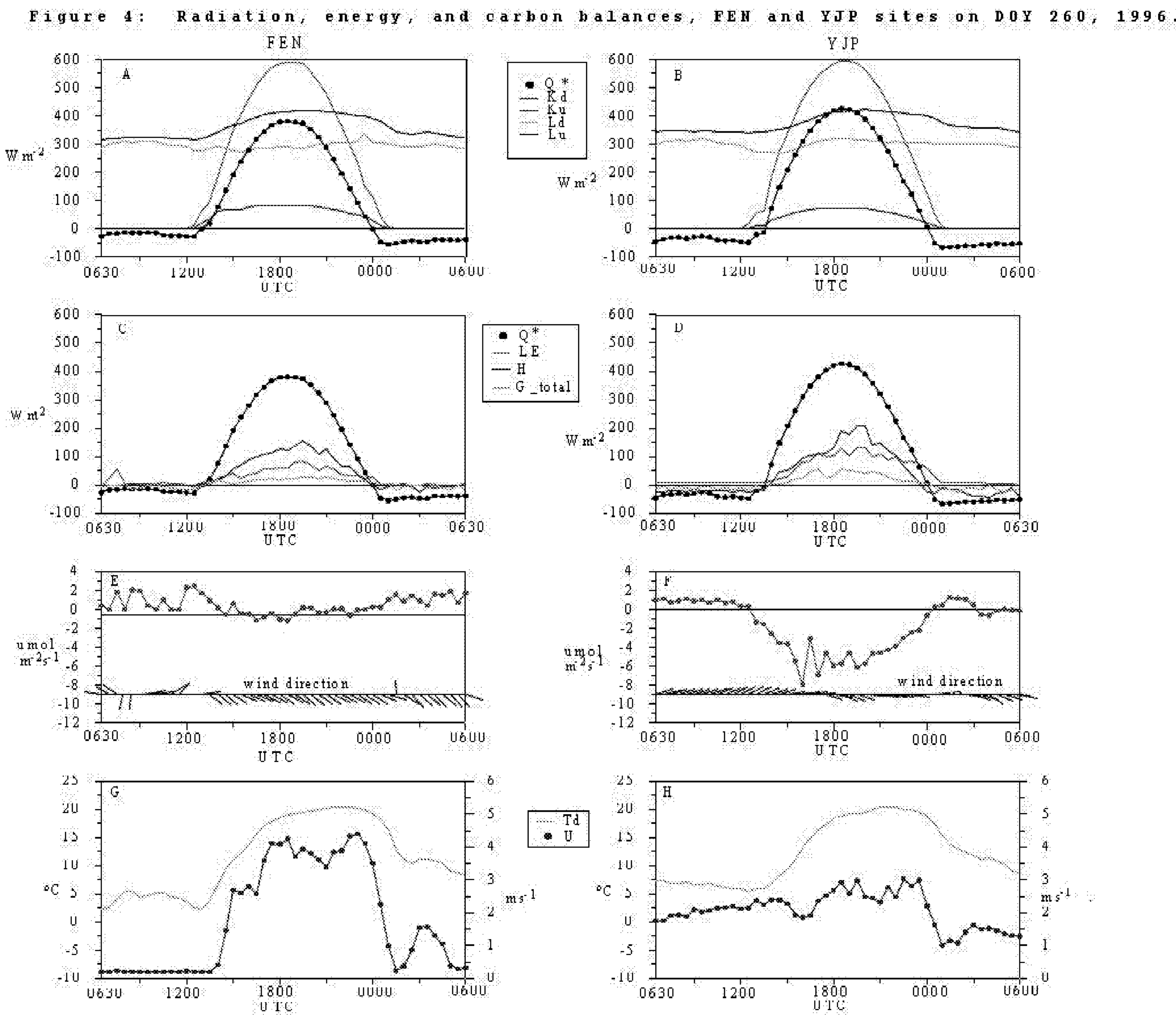

Figure 4: Contrasting Radiation, Energy, and CO_2 Balances Between NSA-Fen and NSA-YJP

10. Errors

10.1 Sources of Error

There are a number of sources of error in the data. In general, these sources can be identified as:

- instrument error, i.e., the error component from the transducer itself
- a component from the measurement device
- a component dependent upon field placement.

Not all of the components of error are easily evaluated, and the most difficult to evaluate through a formal analysis is that due to field placement. We believe that we minimized field placement error, but we do not have a formal way of verifying this claim. We do claim that all instruments were located according to normal field practice, and a close watch was kept by field staff for any apparent aberrant output from the instruments.

10.2 Quality Assessment

All aberrant data occurrences found in the field were noted in the field log and examined in detail during postprocessing. There are a number of reasons for the occurrence of aberrant values. In our particular case, the two most common reasons were i) shutdown of the CO_2 system for calibration, which was done once a day and which resulted in the loss of one 30-minute average value, and ii) covering of the sonic anemometer to prevent its damage by heavy rain. There were various other occurrences of apparently aberrant values unrelated to these two causes. In order to try to identify aberrant behavior more formally, during postprocessing all raw time series were scanned for each day and the outliers from the series were identified and examined in detail. In addition, the calculated time series of fluxes were examined for outliers. Typically, when an outlier was found, the field notes were consulted to see if some action on the tower or in the vicinity of the instrument had been recorded that would have caused the outlier to occur. Irrespective of whether we could tie the outlier to a cause, a simple linear interpolation was applied if the outlier was judged aberrant, the period of bad data was short, and steady state conditions applied. If it was clear that the data point was wrong and it could not be corrected or interpolated, it was flagged and a missing value place holder inserted. It is admitted that this process is not totally objective and it does involve some judgments based upon field experience. We do claim that the data acceptance criteria were conservative; i.e., it was normal to reject an apparently aberrant data point unless there was very strong evidence to the contrary.

10.2.1 Data Validation by Source

The data set has been checked for internal consistency, and all aberrant values have been either removed or interpolated. Aberrant values that could not be interpolated, along with truly missing values, have been designated in the files as missing data. See Section 10.2 for elaboration.

10.2.2 Confidence Level/Accuracy Judgment

The overall best estimate of accuracy of the primary variables are as follows:

```
net radiation:      ± 5%
PPFD:               ± 7%
solar radiation:    ± 1%
soil heat flux:     ± 5% for YJP; no estimate is made for fen
latent heat flux:   ± 15 to 20%
sensible heat flux: ± 15 to 20%
CO2 flux          : ± 20% or ± 0.2 µmol/m2/s, whichever is larger
wind speed (model 12102): ± 0.3 m/s from 0 to 30 m/s
wind direction (model 12302): ± 3.0 degrees
air temperature(T/RH sensor, model 41372): ± 0.3 °C from -50 to + 50 °C
relative humidity (T/RH sensor, model 41372): ± 3% between 10 and 90% RH, and
                     ± 5% between 0 and 10% and between 90 and 100% RH
rainfall (model TE525M, Texas Instruments): ± 1% up to 10 mm/h
                                            ± 3% between 10 and 20 mm/h
                                            ± 5% between 20 and 30 mm/h
```

In 1993, 1995, and 1996, no correction factor was applied to the fen's soil heat flux data. Rather, we report the flux values measured by the plate(s). This is a puzzling result, but if the same correction value had been applied as in 1994, totally unreasonable values of flux would have resulted. In fact, the energy balance closures would have consistently been much greater than unity as a result. This points out the difficulty of measuring heat storage in the peat soil. We suggest that our application of different methodologies can be explained in the following way. In 1994, only the plate in the hollow exhibited any diurnal pattern, but the size and amplitude of the measured flux was tiny. The signal from the plate in the hummock showed zero amplitude, and was a flat line during the whole day, we believe as a result of poor thermal contact between the plate and the peat. Such patterns were not observed in the other sample years, when both plates exhibited similar and significant signal sizes and diurnal amplitudes. Furthermore, accepting the measured fluxes in these sample years results in reasonable energy balance closures. However, the measurement of soil heat flux on a fen remains a confounding problem, and it requires further careful assessment in terms of measurement methodology.

Another problem that caused serious questioning of our methodology was the measurement of the CO_2 flux at night. This problem was most apparent at the YJP. After examination of the data, it was concluded that the measured fluxes should be replaced with modeled values in order to obtain reasonable diurnal patterns. The issue of how best to measure CO_2 fluxes at night under low turbulent mixing conditions remains a priority. In addition, there are outstanding issues on the best way to model the nighttime CO_2 flux.

10.2.3 Measurement Error for Parameters

See Section 10.2.2.

10.2.4 Additional Quality Assessments

None given.

10.2.5 Data Verification by Data Center

Data were examined to check for spikes, values that are four standard deviations from the mean, long periods of constant values, and missing data.

11. Notes

11.1 Limitations of the Data

At this time (June 1998), the data series are not continuous. Where there were measurement problems, e.g., as a result of a sensor failure or a power failure, missing value place holders have been inserted. We are working toward providing robust methods for reconstruction of large data gaps. One method that has been fairly successful is to construct the diurnal patterns of fluxes using ensemble averaging. However, for users who require unbroken time series of 30-minute averages, these data will fall short. In most instances of a small gap, say one or two contiguous half-hours, in a period of steady-state atmospheric conditions, straight linear interpolation should work satisfactorily. If the atmospheric conditions are changing rapidly, or if the gap is large, say half a day, then a rigorous interpolation method will be required. Please consult the PI for progress on the development of interpolation routines for large data gaps.

At this time (June 1998), the eddy covariance flux data (sensible and latent heat and CO_2) at the YJP site are from the Campbell Scientific single-axis sonic anemometer. A second sonic anemometer (Applied Technologies, Inc., (ATI), Boulder, CO, USA) was operational at the site in 1996, and both were located at the same height and orientation on the flux tower. The final calculation of the fluxes based on the ATI sonic data are not yet complete and are not included in this data set.

11.2 Known Problems with the Data

Where tower flux sites do not have adequate upwind fetch, uncertainties are introduced into the interpretation of the flux data. We believe this may have been a problem at the fen. The eddy covariance instruments were located at a height of 4.5 m above the surface. Using the standard micrometeorological "rule-of-thumb" for fetch-to-height ratio of 100:1, a 4500-m fetch is required in all directions around the fen tower. The site did not meet this criterion. Fetch was limited along the northeast shore in the azimuth directions (from magnetic north) 350-0-125 degrees. Minimum fetch in this quadrant was approximately 150 m at a bearing 65 degrees. Similarly, fetch was limited along the south shore in the bearing 160-235 degrees. Minimum fetch in this quadrant was 220 m at the bearing 205 degrees. Fetch in all other directions exceeded 450 m. Measurements for all wind directions were reported in the data set, and users are cautioned as to this possible source of uncertainty.

11.3 Usage Guidance

Data gaps have been filled using linear interpolation. This method applies only to short periods, a few half-hours at best, under steady-state conditions. If the meteorological conditions are changing, linear interpolation fails. It also fails if the data gap is longer than a few half-hours. When we encountered a long data gap, we left the data field blank and assigned a "missing value" place holder. Given that we did have significant gaps in the flux series because of the difficulties of the Campbell sonic anemometer in rainy weather, we have used ensemble averaging to create complete average diurnal curves of fluxes for publications. We recognize that ensemble average data are not necessarily the ideal kind for modelers who prefer unbroken time series for each variable.

11.4 Other Relevant Information

None.

12. Application of the Data Set

These data can be used for various applications. For example, they will provide meteorological input variables for a wide range of models. Also, for those models that estimate fluxes, the data set provides flux data series for sensible and latent heat and CO_2 for model verification.

13. Future Modifications and Plans

Once the data processing is complete, we will submit the convective and CO_2 flux data for YJP in 1996 based on measurements from the ATI sonic anemometer. Secondly, we are working on a more objective method to fill data gaps.

14. Software

14.1 Software Description

The measurement of the raw data was principally on Campbell Scientific data loggers, and all of the specific control programs for these data loggers are available.

A variety of software was used in the data assessment and analysis. STORAG, a Fortran program to find the minor heat storage terms in the energy balance, calculated the surface soil heat flux, the biomass heat storage, and the latent and sensible heat storage in the air up to the level of measurement of net radiation, where the surface balance was closed. RADBAL, a Fortran program to solve the terms of the energy balance, was used in the analysis of the radiation balance data, including the calculation of shortwave and PPFD albedos, and the radiative surface temperatures. We developed a number of QuattroPro spreadsheets for the calculation of convective fluxes (H and LE) and the CO_2 flux, including the correction of the fluxes for density effects and ensemble averaging to construct average daily flux patterns for the days included in the average. Ensemble averaging was used as a means to find the mean diurnal pattern from often incomplete flux data series on individual days. This methodology was successful and was favored over the development of other means for filling data gaps. However, active research on the issue of how best to fill data gaps continues.

14.2 Software Access

All software developed for the analysis of the data is available by contacting J.H. McCaughey (PI).

15. Data Access

The NSA-Fen tower flux and meteorological data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

All persons from Queen's University, Kingston, Ontario, who worked on the flux towers received training on tower climbing techniques, tower rescue methods, and the operation of a safe field site. The material is summarized in McCaughey (1993), and a summary of the training materials can be found in the tower safety document.

The data analysis to find the minor heat storage terms in the energy balance was accomplished with the software program titled STORAG, and details of this software are available in McCaughey (1991).

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

Symbol	Quantity	Units
a	Albedo	dim.
AT	Total needle area	cm2
C	Volumetric heat capacity of soil	J/m3/°C
C'	CO2 concentration per volume fluctuation	ppmv
CF	Correction factor	dim.
Cm	Heat capacity of mineral fraction	J/m3/°C
Co	Heat capacity of organic soil	J/m3/°C
CO2night	Net CO2 flux from model when Kd<5 W/m2	µmol/m2/s
CON	Constant used in STORAG to find heat storage in air, soil, and vegetation	J/m3/°C/s
Cp	Specific heat of air at constant pressure	J/kg/˚C
Cw	Heat capacity of water	J/m3/°C
dbh	Diameter at breast height	cm
de	Rate of change in vapor pressure	kPa/s
dim.	Dimensionless number	dim.
DS	Depth of temperature measurements	m
dTa	Rate of change in air temperature	˚C/s
dTb	Rate of change in biomass temperature	˚C/s
dTs	Rate of change in soil temperature	˚C/s
FeCO2	Eddy flux of CO2 (equivalent to net flux at height of measurement)	µmol/m2/s or mg/m2/s
FsCO2	Storage flux of CO2	µmol/m2/s
FCO2	Total CO2 flux	µmol/m2/s
G	Soil heat flux at surface	W/m2
G(z)	Soil heat flux measured at depth z	W/m2
G10	Heat storage in the soil volume above 10-cm depth	W/m2

Ga	Sensible heat storage in air	W/m2
GB	Heat flux out the bottom of the soil profile at the fen	W/m2
Gcal	Total heat storage in the soil profile at fen	W/m2
Ge	Latent heat storage in air	W/m2
Gfen	Ground heat flux at the fen in 1994	W/m2
Ghol	Ground heat flux in hollow at the fen	W/m2
G(z)n	Soil heat flux at YJP (north site)	W/m2
Gpla	Time-integrated soil flux from plate at fen	W/m2
G(z)w	Soil heat flux at YJP (west site)	W/m2
G_total	Total heat storage	W/m2
G_totaln	Total heat storage at YJP (north site)	W/m2
G_totalw	Total heat storage at YJP (west site)	W/m2
Gveg	Heat storage in biomass at YJP	W/m2
Gvegn	Heat storage in biomass at YJP (north site)	W/m2
Gvegw	Heat storage in biomass at YJP (west site)	W/m2
h	Tree height	m
H	Sensible heat flux	W/m2
HCS	Heat capacity of soil in STORAG	J/m3/°C
Kd	Incoming solar radiation	W/m2
Ku	Reflected solar radiation	W/m2
Ks	Thermal conductivity of saturated peat soil	W/m/K
k	Instrument H2O vapor absorption coefficient	m3/kg/cm
K*	Total shortwave radiation	W/m2
L	Latent heat of vaporization of water	J/kg
LE	Latent heat flux	W/m2
Ld	Incoming longwave radiation	W/m2
Lu	Outgoing longwave radiation	W/m2
L*	Net longwave radiation	W/m2
M	Molecular weight of dry air	Mole
mis.	Missing value	dim.
Mv	Standing green biomass	kg/m2
P	Atmospheric pressure	kPa
PA	Total projected needle area	cm2
PA(S)	Shoot projected area	cm2
PPFDd	Incoming PPFD	µmol/m2/s
PPFDu	Reflected PPFD	µmol/m2/s
Qd	Total incoming radiation	W/m2
QGZ	Soil heat flux from flux plate (for STORAG only)	W/m2
Qu	Total outgoing radiation	W/m2
Q*	Net radiation	W/m2
Q*corr	Corrected net radiation (following Hodges and Smith (1997))	W/m2
q	Water vapor density	g/m3
q'	Water vapor density fluctuation	g/m3
R	Universal gas constant	J/mol/K
R'	Conifer correction factor	dim.
rho	Density of air	kg/m3
rho(c)	Density of CO2	kg/m3
s	Signal voltage from hygrometer	mv
S	Flux equivalent to the heat stored between individual soil layers	W/m2
SH	Specific humidity	g/kg
sSH	Standard deviation of specific humidity	g/kg

T'	Temperature fluctuation	°C
T_air	Air temperature	°C
TB	Biomass temperature in STORAG	°C
Tblw	Stem temperature of large trees (west site)	°C
Tbmw	Stem temperature of medium trees (west site)	°C
Tbsn	Stem temperature of small trees (north site)	°C
Tbsw	Stem temperature of small trees (west site)	°C
TD	Dry bulb temperature in STORAG	°C
TOL	Thickness of organic layer in STORAG	m
Ts	Soil temperature	°C
Ts10avg	Average soil temperature at 10-cm depth	°C
Ts75avg	Average soil temperature at 75-cm depth	°C
TW	Wet-bulb temperature	°C
U	Wind speed	m/s
v	Intercept of the krypton hygrometer calibration	mv
w'	Vertical wind velocity	m/s
x	Path length of the hygrometer	cm
Xm	Soil volumetric mineral fraction	fraction
Xo	Soil volumetric organic soil fraction	fraction
Xw	Soil volumetric water fraction	fraction
XW	Soil moisture content in STORAG	fraction
z	Depth to soil heat flux plate	m
ZCQ	Control variable in STORAG; used to read two variables: height of canopy and heightof net pyrradiometer	m,m
zr	Reference height	m
ZR	Height of net radiation measurement in early version of STORAG	m

19. List of Acronyms

AES - Atmospheric Environment Services
AFM - Airborne Fluxes and Meteorology
ASCII - American Standard Code for Information Interchange
BOREAS - BOReal Ecosystem-Atmosphere Study
BORIS - BOREAS Information System
CCRS - Canada Centre for Remote Sensing
CD-ROM - Compact Disk-Read-Only Memory
CGR - Certified by Group
CPI - Certified by PI
CPI-??? - Certified but questionable
DAAC - Distributed Active Archive Center
DC - Direct Current
DOY - Day of Year
ENBAL - Energy Balance (analysis program)
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
Fen - Fen wetland site
FFC - Focused Field Campaign
FPAR - Fraction of PPFD absorbed by the vegetation canopy
GIS - Geographic Information System
GMT - Greenwich Mean Time
GPS - Global Positioning System

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GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
HYD     - Hydrology
IRGA    - Infrared Gas Analyzer
LAI     - Leaf Area Index
LW      - Longwave
MV      - Mass of Vegetation
N/A     - Not available
NAD83   - North American Datum of 1983
NARC    - National Atmospheric Radiation Center
NASA    - National Aeronautics and Space Administration
NEE     - Net Ecosystem Exchange
NOAA    - National Oceanic and Atmospheric Administration
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
PCQM    - Point Center Quarter Method
PNFI    - Petawawa National Forest Institute
PPFD    - Photosynthetic Photon Flux Density
RADBAL  - Radiation Balance (analysis program)
REBS    - Radiation Energy Balance Systems Inc.
RH      - Relative humidity
RSS     - Remote Sensing Science
SB      - Short, below breast height
SCF     - Shoot Clumping Factor
STORAG  - (heat) storage (analysis program)
SVAT    - Soil-Vegetation-Atmosphere-Transfer
SW      - Shortwave
TA      - Tall, above breast height
TB      - Tall, below breast height
TF      - Tower Flux
URL     - Uniform Resource Locator
UTC     - Universal Time Coordinated
UTM     - Universal Transverse Mercator
WAB     - Wind Aligned Blob
WPL     - Webb, Pearman, and Leuning flux correction
YJP     - Young Jack Pine
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13. ABSTRACT *(Maximum 200 words)*

The BOREAS TF-10 team collected tower flux and meteorological data at two sites, a fen and a young jack pine forest, near Thompson, Manitoba, Canada, as part of BOREAS. A preliminary data set was assembled in August 1993 while field testing the instrument packages, and at both sites data were collected from 15-Aug to 31-Aug. The main experimental period was in 1994, when continuous data were collected from 08-Apr to 23-Sep at the fen site. A very limited experiment was run in the spring/summer of 1995, when the fen site tower was operated from 08-Apr to 14-Jun in support of a hydrology experiment in an adjoining feeder basin. Upon examination of the 1994 data set, it became clear that the behavior of the heat, water, and carbon dioxide fluxes throughout the whole growing season was an important scientific question, and that the 1994 data record was not sufficiently long to capture the character of the seasonal behavior of the fluxes. Thus, the fen site was operated in 1996 in order to collect data from spring melt to autumn freeze-up. Data were collected from 29-Apr to 05-Nov at the fen site. All variables are presented as 30-minute averages. The data are stored in tabular ASCII files.

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